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October 4, 2019

VIA ELECTRONIC FILING

Marlene H. Dortch, Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, DC 20554

**Re: WT Docket No. 17-200
Ex Parte Presentation**

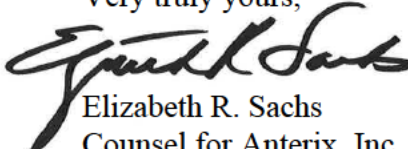
Dear Ms. Dortch:

The Commission's proposal to realign the 900 MHz band (896-901/935-940 MHz) to create a 3/3 megahertz broadband service while reserving two band segments for continued narrowband operations has elicited a number of filings that express views on the potential impact for systems operating on spectrum adjacent to the proposed broadband segment. While Anterix has submitted documentation previously that supports the technical rules proposed by the FCC, the attached presentation again addresses the claims relating to out-of-band-emission ("OOBE"), guard band, and interference-claim threshold concerns that lie at the technical heart of this proceeding.

This letter is being filed electronically, in accordance with Section 1.1206(b) of the Commission's Rules, 47 C.F.R. § 1.1206(b), for inclusion in the record in this proceeding.

Kindly refer any questions or correspondence regarding this matter to the undersigned.

Very truly yours,


Elizabeth R. Sachs
Counsel for Anterix, Inc.

Attachments

cc (via email):
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WT DOCKET NO. 17-200
SUMMARY OF TECHNICAL ISSUES

I. INTRODUCTION AND SUMMARY

The Commission has proposed realigning the 900 MHz band (896-901 /935-940 MHz) from narrowband operations (*i.e.*, 12.5 kHz channels) to a segmented scheme whereby all narrowband operations would operate in two separate segments: a 1.5/1.5 megahertz segment (896-897.5/935-936.5 MHz) below the broadband segment and a 0.5/0.5 megahertz segment (900.5-901/939.5-940 MHz) above the broadband segment.¹ The broadband segment would be at 897.5-900.5/936.5-939.5 MHz,² which would allow for the deployment of a three megahertz broadband LTE channel for a 900 MHz Broadband (“BB”) service. This would provide a much-needed below-1 gigahertz broadband option for critical infrastructure industry users and other enterprise entities, using tested, cost-efficient technology and allowing high speed broadband communications where previously only narrowband low data rate transmissions were permitted.

Parties concerned about permitting the use of broadband technology in the 900 MHz band have focused on three technical areas: (1) out-of-band emission (“OOBE”) attenuation; (2) the need for a guard band between broadband and narrowband services; and (3) a change in the median desired signal strength criteria for narrowband systems that allege unacceptable interference

¹ *Review of the Commission’s Rules Governing the 896-901/935-940 MHz Band*, WT Docket No. 17-200, Notice of Proposed Rulemaking, 34 FCC Rcd 1550 (2019) (“NPRM”).

² Anterix noted in its Comments on the NPRM that 3GPP standards require all LTE carriers to conform to a carrier center in integer multiples of 100 kHz; *i.e.* 938.0000, 938.1000, 938.2000 MHz. The proposed broadband segment of 936.5000-939.5000 MHz will have the carrier center at 938.0000 MHz. This requires that the broadband segment begin at 936.5000 MHz, channel 120, and end at 939.5000 MHz, channel 360, rather than beginning at channel 121 as indicated in footnote 38 in the NPRM (3GPP specification TS36.101-R16, Section 5.7.2 (Devices) and TS36.104-R16 (RAN-eNodeB), Section 5.7.2, 25.7.2A. *See* Comments of PDV Wireless, Inc., WT Docket No. 17-200 at 9-10 (filed May 30, 2019).

caused by broadband operations. The Commission has received substantial record evidence that each of these issues is well managed by the proposed technical rules for the BB service.³ It should move forward rapidly in adopting a Report and Order to allow for use of broadband systems in the 900 MHz band.

First, the asymmetric OOB limits proposed in proposed Section 27.1525 ($43 + 10 \log (P)$ dB for uplink operations in the 897.5-900 .5 MHz band and $50 + 10 \log (P)$ dB for downlink operations in the 936.5-939.5 MHz band) would, combined with the inherent characteristics of an LTE channel, provide appropriate protection to adjacent services. In fact, the proposed rules protect narrowband systems to the same or even better OOB levels than the current regulations for narrowband operations. Moreover, the Commission can adopt additional attenuation requirements for OOB as it has for other broadband services to address unusual cases where unacceptable interference may occur.

Next, there is no need for a guard band to protect adjacent channel systems from broadband operations. A guard band between adjacent narrowband systems and new broadband systems would be needed if: (1) the OOB limits were insufficient; or (2) high-powered broadband operations would lead to receiver desense due to blocking. As discussed in more detail below, the OOB limits proposed by the Commission provide appropriate protections for adjacent band operations.

Similarly, receiver blocking issues should not be an issue in normal broadband network operations as narrowband 900 MHz receivers are well-equipped to deal with a single, strong

³ See, e.g., Comments of Pericle Communications Company (“Pericle”), WT Docket No. 17-200, (filed Sept. 29, 2017) (“Pericle Comments, White Paper”); EWA/PDV Reply Comments, WT Docket No. 17-200, Attachments 1 (“Response to Sensus Comments”) and 2 (“Pericle Study”) (filed Nov. 1, 2017) (“EWA/PDV Reply Comments”); see also Comments of Southern Company Services, Inc., WT Docket No. 17-200 (filed June 3, 2019); Comments of Ericsson, WT Docket No. 17-200 (filed May 31, 2019); Comments of Burns & McDonnell, WT Docket No. 17-200 (filed June 6, 2019).

interferer. LTE handsets operate at significantly lower transmit power than existing narrowband LMR subscriber units – typically 200 milliwatts. Moreover, the LTE network maintains significant power control of mobile units for the uplink segment of network transmissions. As discussed in Section II below, other mechanisms are employed for power and OOB control on the downlink portion of network transmission. In fact, in urban and suburban areas, the LTE handset will operate at least 9 dB below its maximum power 98% of the time and OOB is reduced 1 dB for each 1 dB of power reduction.⁴ Thus, the probability of a strong, coincident interfering broadband signal in proximity to a narrowband receiver is less likely than interference from adjacent narrowband operations.

Finally, in the unlikely event that unacceptable interference does occur, the Commission has proposed, consistent with an Anterix recommendation,⁵ that 900 MHz site-based narrowband incumbent systems that are: (1) experiencing interference; (2) in good repair and operating condition; and (3) receiving a median desired signal strength of -98 dBm as measured at the R.F. input of the receiver of a mobile unit or a median desired signal strength of -95 dBm as measured at the R.F. input of the receiver of a portable (hand-held) unit would be able to seek interference resolution from a broadband licensee.⁶ While Anterix believes that these median signal strengths are the appropriate values, the record has shown that some incumbents believe the interference-claim threshold (“ICT”) should parallel the values used for 800 MHz public safety licensees in Rule Section 90.672. Specifically, these commenters suggest that the median desired signal strength at mobile receivers should be -104 dBm and -101 dBm for portable receivers.

⁴ Commerce Spectrum Management Advisory Committee (CSMAC) Final Report: Working Group 1 – 1695-1710 MHz Meteorological-Satellite, Appendix 3: Baseline LTE Uplink Characteristics, January 22, 2013.

⁵ EWA/PDV Reply Comments, Attachment 1/Exhibit A at 11.

⁶ NPRM at ¶73. Anterix originally had proposed signal strengths consistent with current Rule Section 90.672(i) for 900 MHz systems, but modified its recommendation to the more generous standard proposed in the NPRM.

Anterix remains confident that the values proposed by the Commission would provide an appropriate ICT. It also is confident for the reasons described herein that broadband interference will not occur under ordinary circumstances, but only in the rarest of instances. Therefore, to accommodate the desires of those incumbents and to align the thresholds for 800 and 900 MHz narrowband services, Anterix does not oppose adoption of the more relaxed ICT.

Taken together, the record demonstrates that adjacent band operations would be fully protected by implementation of the Commission's OOB attenuation proposal and without any need for a guard band of spectrum between broadband and narrowband systems. Further, the adoption of a relaxed ICT for 900 MHz narrowband systems and requirements for broadband licensees to further attenuate OOB in cases of interference provide a backstop for resolving any issues that may arise. Anterix recommends that the Commission move forward expeditiously to adopt the technical rules proposed for the BB service, along with a specific provision defining the ICT considered appropriate by the FCC.

II. BACKGROUND

Traditionally, the FCC has enforced interference protection of adjacent band services through transmitter-oriented technical rules and enforced them through the equipment certification process. These rules include: (1) limiting output or radiated power, (2) imposing frequency stability standards, (3) compliance with occupied bandwidth requirements, and/or (4) limiting the energy from a transmitter into an adjacent band. The latter requirement has traditionally been enforced through use of OOB limits depicted as an emission mask, or more recently through adjacent channel power requirements.⁷

⁷ See, e.g., 47 C.F.R. § 90.543 which provides for adjacent channel power requirement in the 769-775 MHz and 799-805 MHz frequency bands and a more traditional emissions mask in the 758-768 MHz and the 788-798 MHz frequency bands.

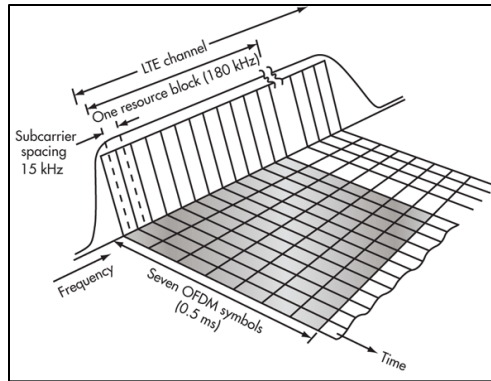
These requirements were developed based on historical modulation techniques where all information was imparted onto a single carrier (*e.g.*, AM, FM, CDMA, etc.). Newer broadband modulation techniques rely on multiple subcarriers spread across a broadband channel bandwidth that simultaneously sends information on each of these subcarrier frequencies. This spreads the emission energy across the channel bandwidth. One of the advantages of this technique is that it allows handsets and fixed devices to transmit back to the base station in a sequenced manner rather than simultaneously, thus reducing the OOB impact.⁸

LTE uses the OFDM modulation scheme and maps the transmissions into resource blocks (unit of frequency for a duration of time). In the uplink, the base station allocates a specific number of resource blocks to a mobile or fixed device and schedules the transmission. Each resource block is 180 kHz wide and 0.5 milliseconds in duration. Thus, for a three megahertz-wide LTE signal, a user can be assigned a maximum of 15 resource blocks.⁹ This translates to maximum raw data rates (before subtracting for overhead) of 5.4 Mbps for QPSK modulation; 10.8 Mbps for 16 QAM; and 16.2 Mbps for 64 QAM.¹⁰

⁸ In LTE terminology, handsets and fixed devices are identified as UEs, user equipment, and base/repeaters are also identified as eNodeBs.

⁹ LTE imposes an internal guard band at the edges of the channel generally equivalent to 10% of the channel bandwidth or 5% on each side of the channel. For a three megahertz LTE channel, that guard band is 300 kHz (or 150 kHz at each end). After accounting for this guard band, dividing the remaining channel by 180 kHz results in 15 distinct segments.

¹⁰ Pericle Comments, White Paper at 10-12. In that filing, Pericle attached a white paper that provides details on the interference scenarios as well as the market studies conducted.



Source: <http://latestfreeupdates.com/ofdma/>

LTE subscribers share resource block access on a time slot basis. Thus, only one subscriber transmits in its assigned frequency segment (one or more 180 kHz-wide resource blocks) at a time in any cell sector.¹¹ On the downlink, the amount of LTE OOB power captured by the narrowband receiver depends on several factors: (1) the path loss from the LTE eNodeB to the narrowband subscriber radio; (2) the LTE base station vertical antenna pattern; (3) the emission mask; and (4) the equivalent noise bandwidth of the narrowband receiver.¹²

III. THE COMMISSION'S PROPOSED OOB LIMITS WILL PROTECT INCUMBENT USERS

The Commission has proposed to establish an OOB attenuation limit outside a broadband licensee's frequency band of operation of at least $43 + 10 \log (P)$ dB for uplink operations in the 897.5-900.5 MHz band and by at least $50 + 10 \log (P)$ dB for downlink operations in the 936.5-939.5 MHz band.¹³ The Commission concluded that the more stringent asymmetrical emission mask proposed would protect Narrowband Personal Communications Service ("NPCS") users

¹¹ *Id.* at 11.

¹² *Id.* 11-12.

¹³ NPRM at ¶74.

from OOB and sought comment on whether its proposed limits would be sufficient to protect narrowband operations in the adjacent narrowband segments.¹⁴

Commenters either generally supported the Commission's proposal¹⁵ or conflated OOB concerns with a need for a guard band.¹⁶ Only the two parties below provided technical information directly relevant to the Commission's OOB proposal.

Gogo had not participated previously in the proceeding, but recently filed an *ex parte* letter raising general concerns about the possibility of interference from 900 MHz broadband devices.¹⁷ It suggested several prophylactic measures the Commission might adopt, including more stringent OOB limits. However, it also acknowledged that the separation between its operations and the proposed 3/3 megahertz broadband segment will help ensure that no interference develops.¹⁸ Anterix and Gogo are scheduling a meeting of their technical experts so Gogo can explain the basis for its concern and the parties can determine what, if any, action needs to be taken.

NextEra (supported by a technical study by Harris Corporation) suggested a need for an OOB limit of $76 + 10 \log (P)$ per 6.25 kHz for downlinks for the 900 MHz narrowband segments, with the $50 + 10 \log (P)$ limit applied to spectrum external to the narrowband segments, and an OOB limit of $65 + 10 \log (P)$ per 6.25 kHz for uplinks.¹⁹ Anterix has demonstrated in the record

¹⁴ *Id.*

¹⁵ See e.g., Comments of Utilities Technology Council, WT Docket No. 17-200, at 28 (filed June 3, 2019) ("UTC also supports the use of an adjacent channel interference metric using $43 + 10 \log (P)$ dB for uplink operations in the 897.5-900.5 MHz band and by at least $50 + 10 \log (p)$ dB for downlink operations in the 936.5-939.5 MHz band.") ("UTC Comments").

¹⁶ See e.g., Reply Comments of The Ad Hoc Refiners Group, WT Docket No. 17-200, at 8 (filed July 2, 2019) ("The out of band energy ("OOB") from broadband operations will likely result in harmful interference to at least some narrowband frequency assignments. Several parties observe that the Commission established a guard band at 800 MHz and at 700 MHz separating the Public Safety broadband and narrowband 700 MHz assignments and recommend that the same be established in the 900 MHz band. The Refiners support this position.") ("Ad Hoc Reply Comments").

¹⁷ See *Ex Parte* Presentation of Gogo Inc., WT Docket No. 17-200, at 3-4 (filed Sept. 11, 2019) ("Gogo Ex Parte").

¹⁸ *Id.* at 3.

¹⁹ Comments of NextEra Energy, Inc., WT Docket No. 17-200, Harris Report at 10-18 (filed June 3, 2019) ("NextEra Comments").

that additional OOB attenuation is unnecessary to ensure no harmful interference to adjacent band incumbents.²⁰

A. The Commission's OOB Proposal Is More Stringent Than Current Requirements

For nearly every other broadband spectrum allocation, the Commission has adopted a standard $43 + 10 \log (P)$ dB attenuation requirement for OOB.²¹ For the 900 MHz band, the Commission has used this for the uplink portion of the band and added an additional 7 dB of attenuation ($50 + 10 \log (P)$ dB) for the downlinks. To simplify discussion, the $43 + 10 \log (P)$ dB factor is equivalent to -13 dBm while the $50 + 10 \log (P)$ dB factor is equivalent to -20 dBm.

The existing Part 90 narrowband emissions are regulated with one mask for analog communications (Mask I) and another for digital communications (Mask J). Under the Part 90 rules, Mask I attenuates to -13 dBm while Mask J attenuates to -20 dBm.²² However, neither emission mask achieves these levels within the assigned channel bandwidth as illustrated in Figure 1. The Part 24 NPCS mask, like Part 90, attenuates to -13 dBm and, similarly, does not achieve this level within its assigned channel bandwidth.²³ As shown in Figure 1, the Commission has proposed to protect adjacent narrowband 900 MHz operations to a greater level at the broadband channel edge.

²⁰ See n. 2 *supra*.

²¹ See e.g., §§22.359(a), 24.238(b), 27.53(g), 27.53(h). The general difference between the OOB limits are focused on the reference bandwidth for the measurements. For 900 MHz, the FCC has proposed that the reference bandwidth be 100 kHz.

²² 47 C.F.R. § 90.210(i) and (j).

²³ 47 C.F.R. § 24.133. There are separate masks for authorized bandwidths of 10 kHz and for greater than 10 kHz.

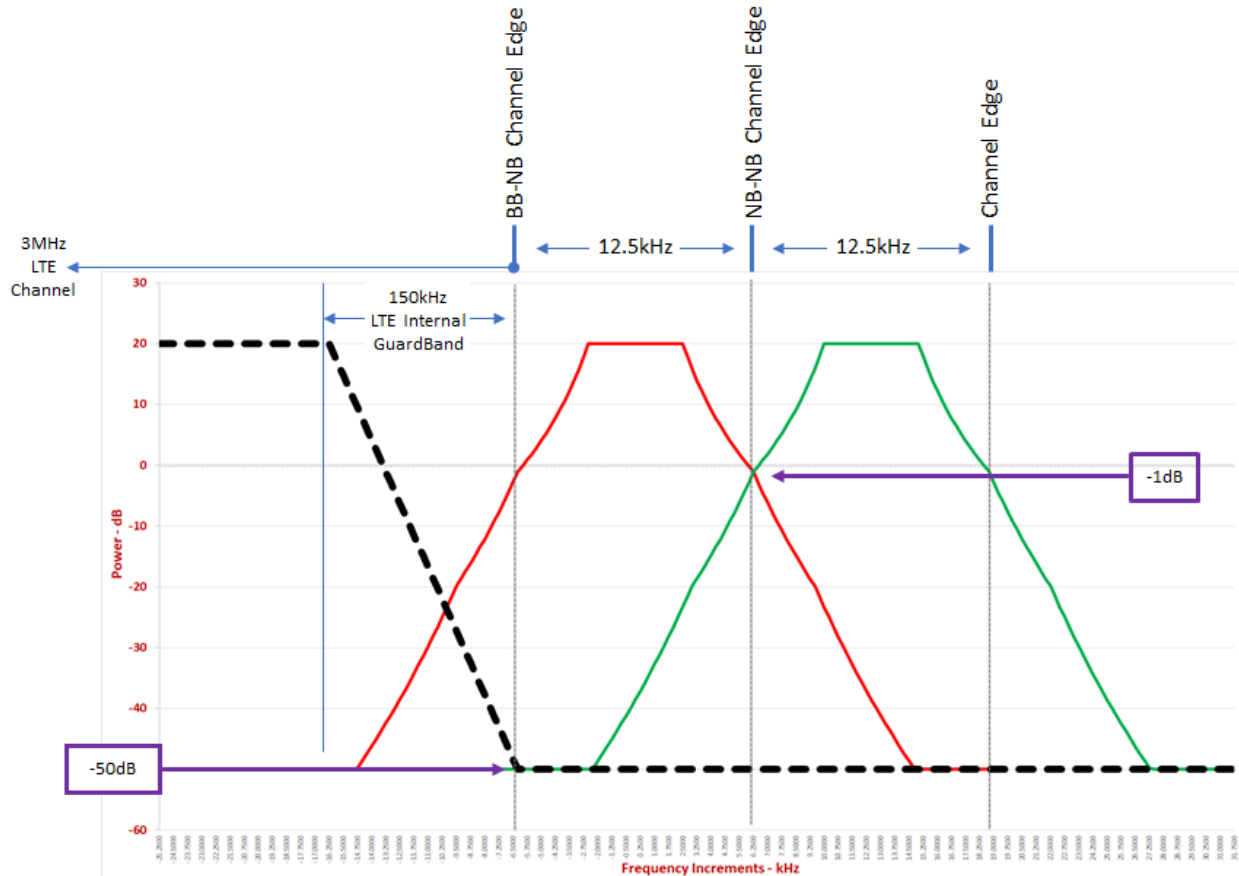


Figure 1 Part 90 Mask J vs Proposed Broadband Downlink $50 + 10 \log (P)$ Emissions

B. Anterix Has Provided Technical Analyses That Demonstrate The Commission's OOB Limits Will Protect Incumbents

Anterix has provided detailed studies by Pericle that analyzed the effects of downlink OOB between an LTE and narrowband system.²⁴ In these studies, Pericle computed the interference environment ($C/(I+N)$) for two cases and compared the difference in potentially affected area for both cases: (1) a three market study (San Antonio, Orlando, and San Diego) based on the downlink emission mask of $50 + 10 \log (P)$,²⁵ and (2) a prospective fully built-out narrowband network for the same three markets with three tall sites assuming protection based on

²⁴ See EWA/PDV Reply Comments, at Attachment 2 (“Pericle Study”). See also, Pericle Comments, White Paper.

²⁵ The Pericle Study used a reference bandwidth of 30 kHz rather than 100 kHz. A $55 + 10 \log (P)$ dB requirement measured in 30 kHz is equivalent to a $50 + 10 \log (P)$ dB requirement measured in 100 kHz. Therefore, the studies are directly consistent with the Commission’s proposed OOB limits.

the Mask I (Section 90.210(i) with an OOB limit of $43 + 10 \log (P)$ dB, 7 dB greater than the LTE downlink case). The criteria used by Pericle to demonstrate that there would be the potential for interference are those found in the current 900 MHz narrowband rules. As demonstrated in the table below, there are areas in the three test markets where the C/(I+N) of the incumbent due to narrowband OOB is below 17 dB.²⁶

Table 1 - C/(I+N) Less Than 17 dB Due to Downlink OOB				
		LTE Carrier (white paper)	Active TX for Part 90 Mask I Equivalent (Breakeven)	Fully Built-Out Part 90 Network (50 TX/Site)
Market	Incumbent	Area Affected	Number of Transmitters	Area Affected
San Antonio, TX	LCRA	0.65%	5	5.6%
Orlando, FL	Duke Energy	0.041%	8	0.71%
San Diego, CA	SDG&E	0.11%	3	3.3%

This analysis provides compelling evidence that the Commission’s proposed downlink OOB limit for the BB service would provide significantly superior protection to incumbent narrowband operations. Indeed, a fully built-out Part 90 narrowband system would create an order of magnitude (factor of 10) more interference in terms of area affected than an LTE system.²⁷ Furthermore, the point at which the narrowband OOB is greater than that of an LTE network in terms of potential area affected is much lower than the fully built-out assumption of 50 channels per site in a market — it is only between 3 and 8 channels per site.²⁸ In simple terms, a narrowband 900 MHz network with between 3 and 8 channels per site would create greater downlink OOB interference than an LTE network.²⁹

²⁶ See 47 C.F.R. § 90.672(a)(1)(ii)(B). See also, Pericle Comments, White Paper at 14. The Pericle White Paper presented all the assumptions used in the modeling of the interference environment, including the propagation model, the propagation software, the actual incumbent site data and ERP used, the usable signal threshold, the delivered audio quality, the site antenna heights, the study area size, and the tile size.

²⁷ Pericle Study at 3.

²⁸ *Id.*

²⁹ *Id.*

In the uplink case, the interference scenario is the effect of OOB from LTE mobile transmitters into a narrowband incumbent's base station receive antenna.³⁰ Receiver intermodulation and blocking would not be at issue because the LTE mobile subscriber radios are low power, typically 200 milliwatts. A narrowband receive antenna is typically high on a tower, thus further reducing the already low probability of an adverse impact. As shown in the table below, based on Pericle's modeling of three markets, the probability of harmful uplink interference is remote, much less than one percent.³¹

Table 2 - C/(I+N) Less Than 17 dB Due to Uplink OOB		
Market	Incumbent	P(C/(I+N)) < 17 dB
San Antonio, TX	LCRA	0.041%
Orlando, FL	Duke Energy	0.025%
San Diego, CA	SDG&E	0.0015%

C. NextEra's Technical Study Is A Static Analysis That Is Based on Worst-Case Conditions

The Harris technical analysis commissioned by NextEra does not demonstrate that narrowband systems will be subject to harmful interference and does not attempt to calculate the probability of such an event.³² Harris simply created an example of a single, worst-case scenario where the C/(I+N) was less than 17 dB and concluded based on that example that "harmful interference" would occur. As the Pericle study showed, there will be instances where the 17 dB

³⁰ Pericle Study at 19-23.

³¹ *Id.* at 23.

³² NextEra Comments, Harris Report at 10-18.

threshold is not met—however, these are rare and unlikely circumstances that would not be construed as “harmful” or probable. All radio systems are subject to strong interfering signals and are designed to mitigate those effects. The Pericle methodology is a more realistic approach that studies the likelihood of effects and the geography associated with those scenarios—and found that the Commission’s proposed OOB limits provided greater protection than those in the current rules governing narrowband services.

The Commission should not, and does not, promulgate technical restrictions and rules based on worst case, static scenarios, as doing so often would prevent the introduction of newer technologies and would erect barriers that would result in the underutilization of spectrum without any concomitant benefits to the public. Instead, the Commission has consistently assessed the likelihood of interference scenarios arising in a spectral environment in which no incumbent is or could be guaranteed entirely interference-free usage and makes a public interest determination. As the Commission has stated:

Furthermore, it is a fundamental reality that every radio communication system must work in the presence of some amount of RF noise and interference. Consequently, communication system designers typically incorporate some built in operational margin that maintains reasonable performance in the face of variables such as anticipated interference/noise levels, component degradation over time, temperature-related circuit fluctuations, the impact on signal levels from the weather, and the like. In other words, the system design must include some reasonable margin for acceptable performance in a changing environment.³³

³³ Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands, ET Docket No. 03-237, *Notice of Inquiry and Notice of Proposed Rulemaking*, 18 FCC Rcd 25309 at ¶ 27 (2003).

D. Gogo's Request Does Not Demonstrate Any Harmful Interference Would Occur

As stated above, Anterix intends to discuss Gogo's very recent request for protection from interference with that company. Upon initial review, however, Anterix does not believe that any interference should be anticipated for the reasons discussed below.

Initially, as described in detail above, the OOB limit on broadband systems exceeds the existing protection for adjacent band operations. Moreover, broadband operations in the 900 MHz band would be more than 1.5 megahertz away from the Air-to-Ground ("ATG") spectrum band in which Gogo operates—providing even more frequency separation from any interfering signal. Further, the interference from broadband 900 MHz operations would be on the uplink, which means that the mobile device would have to be extremely close to an ATG base station to present any interference effects. Finally, Gogo has raised similar OOB concerns in a prior Commission proceeding. In the Cellular Reform proceeding, Gogo asserted that use of a Power Spectral Density model for the Cellular Service would result in increased risk of OOB interference to Gogo's ATG operations in the adjacent band.³⁴ While the interference scenario was downlink rather than uplink, the Commission's arguments rejecting Gogo's request are applicable here as well. The Commission noted that it expects licensees to work together to resolve interference issues and encouraged Gogo to work proactively to avoid increased interference among licensees.³⁵

³⁴ See Amendment of Parts 1 and 22 of the Commission's Rules with Regard to the Cellular Service, Including Changes in Licensing of Unserved Area, Amendment of the Commission's Rules with Regard to Relocation of Part 24 to Part 27; Interim Restrictions and Procedures for Cellular Service Applications; Amendment of Parts 0, 1, and 22 of the Commission's Rules with Regard to Frequency Coordination for the Cellular Service; Amendment of the Commission's Rules Governing Radiated Power Limits for the Cellular Service; Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 to Establish Uniform License Renewal, Discontinuance of Operation, and Geographic Partitioning and Spectrum Disaggregation Rules and Policies for Certain Wireless Radio Services; 2016 Biennial Review of Telecommunications Regulations, WT Docket Nos. 12-40, 10-112, and 16-138, RM Nos. 11510 and 11660, *Second Report and Order, Report and Order, and Second Further Notice of Proposed Rulemaking*, 32 FCC Rcd 2518 at ¶103 (2017).

³⁵ *Id.* at ¶105.

Anterix has already committed to work collaboratively with Gogo. No further action need be taken by the Commission.

E. The Commission Can Adopt Mechanisms To Mitigate Any Rare Interference Cases

While Anterix is confident that no incumbent will receive harmful interference from the proposed BB service, the Commission can adopt additional remedies that will allow for rapid mediation should such a situation arise. First, as commenters, including Anterix, have suggested,³⁶ the Commission could adopt a requirement that a broadband licensee attenuate its signal more than required by the rules in the event of OOB interference. The rule can be modeled on existing rules such as Section 27.53(n):

When an emission outside of the authorized bandwidth causes harmful interference, the Commission may, at its discretion, require greater attenuation than specified in this section.³⁷

In addition, the Commission's proposed Section 27.1519(b) limits the power flux density ("PFD") of broadband base and repeaters stations that exceed specified power limits so they do not exceed a modeled PFD of 3000 microwatts/m²/MHz over at least 98% of the area within 1 km of the base or repeater station antenna, at 1.6 meters above ground level.³⁸ Adoption of these two mechanisms should further bolster the ability of incumbents and the Commission to remedy any rare instances of interference that may occur.

IV. THE RECORD DEMONSTRATES THAT THERE IS NO NEED FOR A GUARD BAND BETWEEN BROADBAND AND NARROWBAND OPERATIONS

The Commission has noted that the placement of a 3/3 megahertz broadband license at 897.5-900.5 MHz/936.5-939.5 MHz would create 1.5 megahertz of separation between 900 MHz

³⁶ See e.g., Comments of Sensus USA, Inc., WT Docket No. 17-200, at 2 (filed June 3, 2019); Reply Comments of Space Data Corporation, WT Docket No. 17-200, at 2-3 (filed July 2, 2019); Reply Comments of Lower Colorado River Authority, WT Docket No. 17-200, at 24-5 (filed July 2, 2019).

³⁷ Anterix would suggest this language could be added as a new Section 27.1525(e) in the Commission's rules.

³⁸ NPRM, proposed 47 C.F.R. § 27.1519(b).

broadband operations, and adjacent ATG and fixed microwave systems and would also provide 500 kilohertz of separation between broadband operations and NPCS operations.³⁹ The FCC asserted that this would protect the ATG Service, fixed, and NPCS users from harmful interference, and, additionally, would allow greater separation between co-located narrowband channels, by establishing spectrally separated narrowband segments.⁴⁰

A variety of commenters have suggested that there is a need for a guard band between narrowband and broadband operations.⁴¹ None of these parties have presented technical evidence that a guard band is needed. The only technical evidence in the record for a guard band was contained in the Harris Report, but even that report fails to provide any technical analysis to show that a guard band is needed. Instead, it focuses on comparing the 900 MHz band to the protections adopted in the 800 MHz band, rather than modeling the interference environment as proposed by the Commission.⁴² Additionally, the GPA Study associated with the NextEra comments alleges that 900 MHz B/ILT narrowband incumbents would only have a 150 kHz transition band, and that amount of spectrum is insufficient to implement an external filter should there be a severe case of interference from a broadband licensee.⁴³ In fact, external filters with various levels of attenuation (3-20db) have been the norm in the mobile industry for years. The holds true for LTE at 900MHz as with any other broadband allocation.

³⁹ NPRM at ¶74.

⁴⁰ *Id.*

⁴¹ See e.g., Comments of JVCKENWOOD USA Corporation, WT Docket No. 17-200, at 14-15 (filed June 3, 2019); Comments of Lower Colorado River Authority, WT Docket No. 17-200, at 9 (filed June 3, 2019); Comments of the Utilities Technology Council, WT Docket No. 17-200, at 8 (filed June 3, 2019) (“UTC Comments”); Reply Comments of Caesars Entertainment Corporation, WT Docket No. 17-200, at 7; Reply Comments of The Ad Hoc Refiners Group, WT Docket No. 17-200, at 8.

⁴² NextEra Comments, Harris Report at 10-18.

⁴³ NextEra Comments, Gillespie, Prudhon & Associates, Inc. (“GPA”) Study at 9.

The only substantive technical record evidence provided to the Commission was in the Pericle analysis.⁴⁴ Pericle measured signal rejection of three typical 900 MHz narrowband subscriber radios, that are actually deployed by incumbent operators.⁴⁵ This study was performed using an LTE carrier as the interfering signal and used a 900 MHz scenario that was based on a standard 800 MHz scenario to see if the 900 MHz case would be worse or better than the 800 MHz case.⁴⁶ This study found that the 900 MHz subscriber, who would have no guard band, would have an interference situation that is no worse, and in some cases better, than the 800 MHz user who benefits from a two megahertz guard band.⁴⁷ As the 800 MHz scenario tested is what has been used to resolve interference by the Commission, and has been demonstrated to be acceptable for public safety users, a 900 MHz band plan with no guard band should be acceptable from an interference standpoint as well. No party provided any technical evidence that the combination of stringent OOB limits and receiver blocking performance could not fully protect adjacent band narrowband systems. Pericle's technical study, utilizing performance specifications of actual equipment in a real-world operating environment, demonstrates that broadband is as good a neighbor, and in most cases a better neighbor, than other narrowband systems under the technical rules proposed by the Commission. With spectrum resources scarce, especially in spectrum bands below 1 GHz, managing potential interference through rigorous technical standards (based on actual technical analyses provided in the record) is preferable to allowing spectrum to lay fallow as a guard band.

⁴⁴ See Pericle Comments, White Paper at 24-28.

⁴⁵ *Id.* at 25.

⁴⁶ *Id.* at 5.

⁴⁷ *Id.* at 25.

V. THE USE OF AN INTERFERENCE-CLAIM THRESHOLD WILL ENABLE INCUMBENTS TO MEDIATE ANY INTERFERENCE ISSUES

Structurally similar to the requirements of Section 90.672(a)(1)(i)(A)-(B), the Commission proposed to define unacceptable interference to 900 MHz B/ILT incumbents as occurring when the following conditions are met:

1. A transceiver at a site at which interference is encountered is in good repair and operating condition and is receiving:
 - a. A median desired signal strength of -98 dBm as measured at the R.F. input of the receiver of a mobile unit; or
 - b. A median desired signal strength of -95 dBm as measured at the R.F. input of a portable (hand-held) unit.⁴⁸

The FCC also noted that rule establishes signal levels of -88 dBm/ -85 dBm for 900 MHz mobiles and portables respectively. Thus, the FCC's proposal, based on input from Anterix, would relax the desired signal strength for 900 MHz narrowband operators by 10 dB from the existing rule.⁴⁹

Some commenters have suggested that the Commission align the 900 MHz interference standard with the one used for 800 MHz public safety systems, which is -104 dBm at the mobile; -101 dBm at a portable, when the C/(I+N) is lower than 20 dB.⁵⁰ The Commission proposals of -98 dBm/-95 dBm as the threshold for making an interference claim would be protective of systems designed with an appropriate level of robustness to operate effectively under the current 900 MHz Band rules. This level would be consistent with ensuring that new broadband operations would have no greater impact on the noise floor than would the narrowband systems authorized to operate in the band today.

⁴⁸ NPRM at ¶73.

⁴⁹ *Id.*

⁵⁰ See e.g., Comments of the Critical Infrastructure Coalition, WT Docket No. 17-200, at 7-8 (filed June 3, 2019); Comments of NextEra Energy, Inc., WT Docket No. 17-200, at 19 (filed June 3, 2019); Comments of Duke Energy Corporation, WT Docket No. 17-200, at 19 (filed June 3, 2019); Reply Comments of Utilities Technology Council, WT Docket No. 17-200, at 21 (filed July 2, 2019).

However, to accommodate the concerns of the critical infrastructure industry, Anterix would accept adjusting the median desired signal levels to be consistent with those in place for the 800 MHz public safety band (*i.e.*, -104 dBm at receiver of a mobile unit and -101 dBm at receiver of a portable unit). By relaxing the median desired signal strength criteria, operators of narrowband systems will be assured that even in weak signal environments, they will have the ability to work collaboratively with new broadband licensees to mitigate any interference issues that may arise.

EXHIBIT A

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of)	
)	
Review of the Commission’s Rules Governing the)	WT Docket No. 17-200
896-901/935-940 MHz Band)	
)	
Realignment of the 896-901/935-940 MHz Band to)	RM-11738
Create a Private Enterprise Broadband Allocation)	(Terminated)
)	
Amendment of the Commission’s Rules to Allow)	RM-11755
for Specialized Mobile Radio Services Over 900)	(Terminated)
MHz Business/Industrial Land Transportation)	
Frequencies)	

To: The Commission

COMMENTS OF PERICLE COMMUNICATIONS COMPANY

These comments are submitted in response to FCC 17-108, Notice of Inquiry, adopted August 4, 2017.

Pericle Communications Company (“Pericle”) is a consulting engineering firm specializing in wireless communications. Founded in 1992, Pericle consults for the public safety, personal wireless, transportation, utility and broadcast industries. Through its client, the City and County of Denver, the company was deeply involved in the formulation of the 800 MHz rebanding plan adopted by the Commission in 2004. Pericle continues to help public safety agencies hunt down and resolve 800 MHz interference, including recent work for the City of Oakland, California.

Our firm has considerable experience and depth of knowledge regarding co-existence of narrowband land mobile radio users and broadband cellular base stations. Consequently, pdvWireless, a petitioner in RM-11738, retained Pericle to conduct a study and produce a white paper addressing the technical impacts of subdividing the 900 MHz band into a 2x2 MHz narrowband segment and a 3x3 MHz broadband segment employing the LTE standard. The attached white paper summarizes the results of this study and addresses many of the FCC's questions found in paragraph 40 of the NOI.

In the white paper, we analyze both uplink and downlink interference mechanisms that can potentially affect Part 90 and Part 24 incumbent users. While the FCC does not adopt any specific proposal for realignment in its NOI, we have assumed the Petitioners' proposal for the purpose of assessing technical impacts to incumbent licensees (see RM-11738 comments). Traditionally, the FCC has allocated guard bands between dissimilar wireless services to help prevent interference resulting from the *near/far* problem where a narrowband user is attempting to receive a weak signal from a distant repeater while simultaneously facing interference from strong broadband carrier. But guard bands waste spectrum. Petitioners in the RM-11738 proceeding proposed no guard band, with narrowband users operating immediately adjacent to the 3 MHz broadband segment. One of the key questions is whether narrowband and broadband users can co-exist under this scenario?

To answer this question, three types of potential interference were analyzed:

- Downlink Out-of-Band Emissions (OOBE)
- Uplink OOBE
- Receiver-induced interference (blocking and spectral regrowth)

To understand the effect of out-of-band emissions, we modeled 900 MHz incumbent desired signals from actual sites and broadband LTE interference from a typical network. Three markets were modeled: San Antonio, TX; Orlando, FL and San Diego, CA. For broadband downlink interference, we found that out-of-band emissions resulted in predicted $C/(I+N)$ values less than 17 dB (an established minimum standard, see § 90.672) in a small number of study tiles (less than 1%), in all three markets. Potential uplink interference was predicted to be even more rare, *much* less than 1% of the service area, primarily due to the limited number of simultaneous broadband subscribers under the LTE airlink standard and the fact that LTE subscribers operate with at least 9 dB backoff over 98% of the time.

Another type of potential interference is receiver-induced strong signal interference which typically manifests itself as blocking or spectral regrowth in the receiver's low noise amplifier. The land mobile radio receiver is a complex device with performance that is very much vendor-dependent and the best way to assess receiver performance is to measure it, which we did. These measurements show that typical radios operating in the 900 MHz band perform quite well adjacent to a 3 MHz-wide LTE carrier. In fact, they perform as well without a guard band as some of the best-performing public safety radios when faced with the more familiar broadband interference problem at 800 MHz.

We conclude that a 3 MHz broadband LTE carrier operating from 937 to 940 MHz can co-exist with narrowband Part 90 and Part 24 incumbents. In the rare case of harmful interference, we propose remedies similar to those found in § 90.672 (which also has existing remedies) and § 22.913, including a Power Flux Density (PFD) limit of 3,000 $\mu\text{W}/\text{m}^2$ to harmonize in part with § 22.913(b).

Other recommendations include methods for limiting OOB and high power flux densities at ground level, including

- Avoiding siting broadband antennas close to the ground
- Co-locating the broadband cell site with the incumbent when possible
- Employing broadband cell site antennas with suppressed sidelobes
- Installing bandpass cavity filters with greater rejection outside the 3 MHz segment

Respectfully submitted,

PERICLE COMMUNICATIONS COMPANY

By

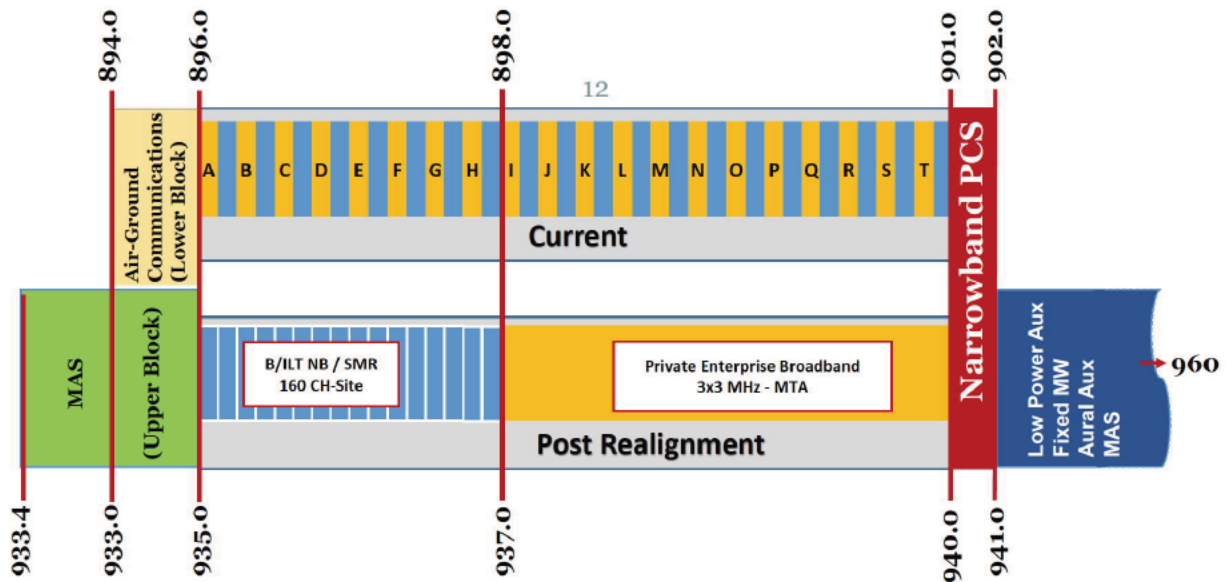


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October 2, 2017

Attachment: White Paper, "Technical Impacts of a 900 MHz Private Enterprise
Broadband Allocation," September 29, 2017.

Technical Impacts of a 900 MHz Private Enterprise Broadband Allocation



September 29, 2017

Prepared for:

pdvWireless

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Technical Impacts of a 900 MHz Private Enterprise Broadband Allocation

1.0 Executive Summary

In late 2014, the Enterprise Wireless Alliance (EWA) and Pacific Datavision, Inc. (“pdvWireless”) (collectively, “Petitioners”) jointly filed a Petition for Rulemaking with the FCC to subdivide the 900 MHz land mobile radio band into narrowband and broadband segments. The Petitioners sought to create a 3x3 MHz broadband wireless service at 900 MHz to support the business enterprise community, especially the critical infrastructure industry (CII), with push-to-talk voice, high speed data and other broadband services [1].

The FCC solicited comments on this petition and numerous comments were filed by interested parties expressing concern about co-existence among incumbent narrowband radio systems and a broadband LTE carrier. On August 4, 2017, the FCC terminated the petition proceeding and adopted a Notice of Inquiry (NOI) to “... begin a proceeding to examine whether any rule changes may be appropriate to increase access to spectrum, improve spectrum efficiency, and expand flexibility in the 896-901/935-940 MHz band (900 MHz band) for next generation technologies and services” [13].

Our firm was asked by pdvWireless to conduct a study aimed at answering questions posed by the FCC in the NOI. This study has three objectives:

- Provide an independent view of the technical impacts of a 900 MHz band realignment
- Create a greater understanding of the technical challenges involved
- Propose methods to mitigate the occurrence of harmful interference should it occur

This white paper specifically seeks to address the questions raised by paragraph 40 of the NOI:

“40. *Technical rules.* We generally seek comment on whether any changes to the technical rules are necessary to keep pace with changing technology, to ensure that this band is used efficiently, and to prevent interference to in-band or adjacent-band licensees. For example, if the Commission were to create a broadband service in the 900 MHz band, it would need to consider rule changes to avoid interference between a broadband licensee and narrowband licensees in adjacent spectrum segments and possible rule changes to avoid interference to services in adjacent bands. We seek comment on the rules that would be necessary, what physical and technical parameters commenters suggest, and whether those rules and parameters would be sufficient to prevent disruption to low-latency, high-reliability utility operations. We also seek comment on what measures would be appropriate to avoid interference between co-channel broadband licensees. What factors should be considered in developing these technical rules? For example, are the receivers in the adjacent services designed to appropriately filter unwanted emissions?”

In this white paper, we analyze both uplink and downlink interference mechanisms that can potentially affect Part 90 and Part 24 incumbent users.¹ While the FCC does not adopt any specific proposal for realignment in its NOI, we have assumed the Petitioners' proposal for the purpose of assessing technical impacts to incumbent licensees. Most of our conclusions apply generally to broadband/narrowband coexistence at 900 MHz.

We conclude that the potential for harmful OOB interference from a 900 MHz broadband carrier does exist on both the downlink and uplink paths, but the potential is low and can be further minimized by limiting out-of-band emissions to a $55+10\log_{10}(P)$ dB emission mask (measured in a 30 kHz bandwidth)² and by applying good engineering practice tailored to the specific circumstances present in the 900 MHz band and the specific market.

On the downlink path, our modeling and analysis shows harmful interference could possibly occur near the broadband cell site, especially when incumbent downlink signals are weak. But this harmful interference is typically confined to less than 1% of the service area. If additional interference reduction is needed, four mitigation techniques should be considered:

- Do not site broadband antennas close to the ground
- Co-locate the broadband cell site with the incumbent when possible
- Employ broadband cell site sector antennas with suppressed sidelobes
- Install bandpass cavity filters with greater rejection outside the 3 MHz segment

Of these, a 12 dB or 22 dB bandpass cavity filter (rejection at band edge) is the most straightforward approach and might be considered for use at all broadband cell sites for consistency.³ Similarly, using an antenna with suppressed sidelobes in the elevation pattern could also be considered for all cell sites because it reduces out-of-band emissions at ground level *and* because it reduces the interfering signal amplitude to values below the threshold where blocking or spectral regrowth is likely to occur in the narrowband subscriber unit. Similarly, avoiding unusually low antenna heights also reduces strong signals on the ground.

Our analysis of uplink interference from LTE mobile subscribers shows even fewer cases of potential interference with much less than 1% of the service area could be potentially affected by harmful OOB. Mitigation of uplink interference is more difficult to achieve than downlink

¹In land mobile radio the terms *outbound*, *talk-out* and *inbound*, *talk-in* are also used. In cellular radio, the terms *forward path* and *reverse path* are also used. The LTE base station is called the eNodeB, but we will use the more generic term *base station* for the LTE fixed site and *repeater* for the narrowband incumbent fixed site.

² Or equivalently, $50+10\log_{10}(P)$ attenuation in a 100 kHz bandwidth.

³ See Appendix C for a datasheet from CCI showing a cavity bandpass filter with at least 25 dB rejection at the broadband channel edge.

interference, but the very small percentages of the service area potentially affected by harmful interference indicate that mitigation should rarely, if ever, be required.

Receiver-induced interference (e.g., blocking and spectral regrowth) was measured on the bench for three typical 900 MHz subscriber radios.⁴ Strong signal interference rejection was quite good for the three models of radio measured, even at the narrowband channel immediately adjacent to the LTE carrier (936.9875 MHz).

To put this subscriber performance in perspective, it helps to compare it to the 800 MHz interference problem faced by public safety users. Public safety users generally operate from 851 to 860 MHz with three cellular operators operating from 862 to 894 MHz. The nearest is Sprint who operates a nationwide cellular network with a 1.25 MHz-wide CDMA carrier and a 5 MHz-wide LTE carrier between 862 and 869 MHz. The public safety radio is also exposed to strong signals from the A-Band operator who may be transmitting multiple CDMA, UMTS or LTE carriers between 869 and 880 MHz. Frequencies above 880 MHz are typically attenuated by the front end filter in the receiver. Thus, public safety users are faced at times with interference from at least two broadband carriers, but they benefit from a 2 MHz guard band.

To compare the two interference scenarios (900 MHz and 800 MHz), we also measured the same three subscriber radios under the 800 MHz scenario with two broadband interfering carriers. Measurements show that interference rejection at 900 MHz matched or exceeded performance of the emulated 800 MHz case, a situation that is generally considered acceptable provided good performing radios are used (like the ones tested for this study). This is an interesting and far-reaching result because it shows that interference from a single LTE carrier with no guard band is no worse than interference from two broadband carriers with a 2 MHz effective guard band (the 800 MHz case).

It is also important to note that the best performing radios at both 800 MHz and 900 MHz do not employ bandpass filters to reject cellular carrier interference (the most obvious solution) because of practical limitations, but instead employ sophisticated RF Automatic Gain Control (AGC) algorithms to mitigate non-linear effects of strong interfering signals.

There could still be rare occasions when harmful interference occurs. In these cases, there should be remedies for the incumbent and these remedies should be captured in new FCC rules that follow precedents set in rulings for the 800 MHz band [4], [8]. Specifically, these new rules should stipulate the following:

- Incumbents are entitled to remedies if their desired signal is above a threshold such as -98 dBm for mobile units and -95 dBm for portable units.

⁴ Blocking and spectral regrowth are defined in Section 3.0 of this white paper.

- For strong signal receiver-induced interference, the incumbent is entitled to remedies if the Power Flux Density (PFD) of the interfering signal exceeds $3,000 \mu\text{W}/\text{m}^2$.
- The broadband carrier should notify incumbents in advance of new cell site construction.
- Out-of-band emissions for broadband base stations shall be attenuated by at least $55+10\log_{10}(P)$ dB measured in a 30 kHz bandwidth or $50+10\log_{10}(P)$ dB measured in a 100 kHz bandwidth.

The remainder of this report is organized as follows: Section 2.0 describes the EWA and pdvWireless joint petition which is the only specific proposal for 900 MHz realignment. Section 3.0 explains the types of radio frequency interference that might occur as the result of the 900 MHz realignment. Section 4.0 addresses interference and transmitter combiner impacts on Part 90 narrowband incumbents while Section 5.0 addresses the same issues with Part 24 users. Section 6.0 suggests new FCC Part 90 rules to mitigate any interference that might occur. Section 7.0 concludes the report with a summary of the key findings and recommendations. Appendix A provides coverage and interference maps for three typical markets analyzed for OOBE interference. Appendix B is the test plan for measuring strong signal interference rejection in the subscriber receiver. Appendix C contains manufacturer datasheets for 900 MHz transmitter combiners, cavity filters and 900 MHz broadband base station and subscriber radios. Appendix D derives the relationship between Power Flux Density and power at the antenna terminal.

2.0 The EWA and pdvWireless Petition

Today, the 900 MHz band consists of two 5 MHz sub bands: 935-940 MHz for downlink and 896-901 MHz for uplink, a total of 399 12.5 kHz channel pairs. The Petitioners stated that a realignment of the 900 MHz band presents a rare opportunity to create a broadband service for business enterprise entities, including CII users, some of whom are current licensees in this band [1]. The Petitioners propose a realignment with the following technical characteristics:⁵

- A 3x3 MHz broadband segment at 898-901 MHz and 937-940 MHz
- A 2x2 MHz narrowband segment at 896-898 MHz and 935-937 MHz
- Broadband segment to be assigned to the entity in each MTA holding at least 15 of the 20 wide-area geographic (YD) licenses available. This Private Enterprise Broadband (PEBB) licensee would fund the relocation of existing narrowband licensees in the broadband segment to comparable facilities either in the narrowband segment or elsewhere.
- No guard band, but a stringent out-of-band emission requirement of $55+10\log_{10}(P)$ dB in

⁵ Some of these points were not included in the original Petition but were offered by the Petitioners in reply comments.

a 30 kHz bandwidth where P is the transmitter power in Watts.⁶ This emissions requirement applies to all emissions outside the 3 MHz band segment and applies to both fixed base stations and mobile subscriber stations.

- Fixed base stations in urban and suburban areas would have a maximum ERP as a function of power spectral density with values harmonized with existing 700 MHz and 800 MHz rules for cellular radio.
- Mobile subscriber stations would be limited to 3W ERP and portable stations would be limited to 1W ERP.

The FCC solicited comments on the Petition for Rulemaking via its Public Notice, dated November 26, 2014 [2]. Many of the comments addressed the technical feasibility of the proposed broadband realignment and these comments informed the FCC's questions in the NOI. Because many of these questions concern the potential for harmful interference, we first define the types of radio frequency interference relevant to this situation.

3.0 Types of Potential Interference

Interference between dissimilar services at band edges is a reasonable concern that has been addressed in past proceedings, including 800 MHz rebanding [4]. In the 900 MHz case, there are two types of users at the band (or segment) edges: Part 90 narrowband LMR users and Part 24 Narrowband PCS (NPCS) users. The band relationship is shown in Figure 1.

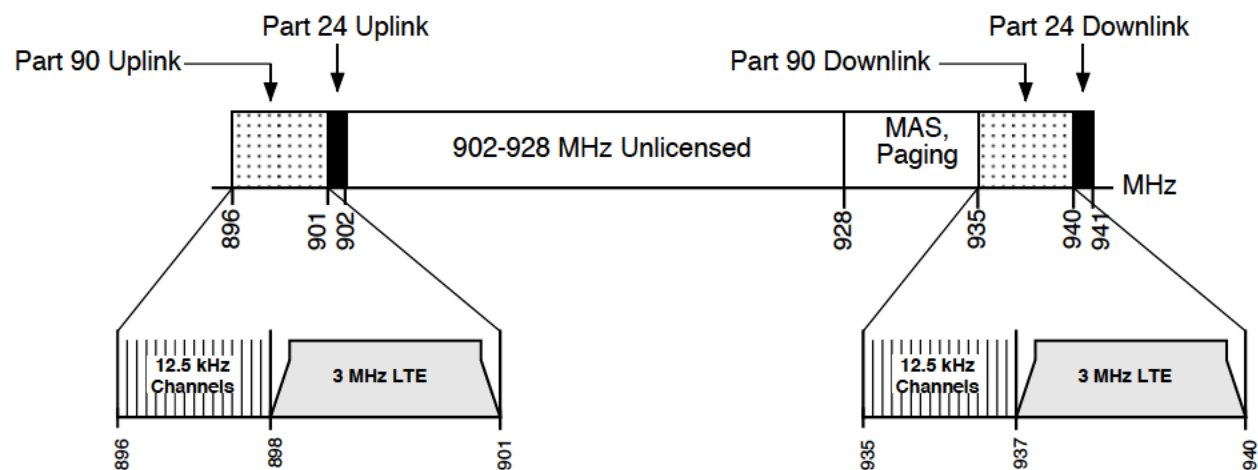


Figure 1 - 900 MHz Band Plan as Proposed by EWA and pdvWireless

⁶ Ex Parte Comments of EWA/PDV, Proposed 900 MHz PEBB Allocation Rules, RM-11738 (filed May 3, 2015).

Part 90 subscribers are primarily LMR devices operating through fixed repeater sites while Part 24 users are primarily smart meters also operating through fixed collection sites, although the communications protocol is quite different than push-to-talk radio.

3.1 Types of Broadband Interference

Potential interference from the broadband system falls into several different categories, but all are a consequence of the *near/far problem* where a narrowband user is operating in the immediate vicinity of a broadband base station or a broadband user is operating near a narrowband repeater site. The relevant types of interference are the following:

- Transmitter out-of-band-emissions (OOBE)
- Receiver intermodulation (IM)
- Receiver-induced spectral regrowth
- Receiver blocking (also called receiver *overload*)

Interference can occur either on the *downlink path* (base station to subscriber) or the *uplink path* (subscriber to base station).

For our purposes, transmitter OOBE will be modeled by the Petitioners' proposed emission mask of $55 + 10\log_{10}(P)$ dB attenuation below the transmitter power in a 30 kHz bandwidth or more simply, -25 dBm in a 30 kHz bandwidth.

The type of receiver intermodulation that is of most concern is *strong signal* receiver IM where the interfering signals range from -50 dBm to -10 dBm. Several of the comments during the petition proceeding compared the 900 MHz realignment to the 800 MHz public safety interference problem. It is helpful to compare and contrast the two situations. Strong signal receiver IM is a serious problem for some 800 MHz public safety radios because they are susceptible to interference from Sprint 800 MHz base stations where a CDMA and an LTE carrier are present and also from cellular A-Band cell sites where multiple broadband carriers are present. Co-located Sprint 800 MHz and cellular A-Band cell sites also introduce IM products between the two wireless providers and this co-location constitutes the worst-case 800 MHz interference situation.

In the 800 MHz band, Sprint deploys a 1.25 MHz-wide CDMA carrier at 862.9 MHz and a 5 MHz-wide LTE carrier at 866.3 MHz. The cellular A-Band operator may deploy a UMTS (3G) carrier, CDMA carrier or LTE carrier above 869 MHz. The potential third-order products in the 800 MHz band (2A-B type) are shown in Figure 2. We see from Figure 2 that some of these IM products span the entire 800 MHz public safety band (851-861 MHz).

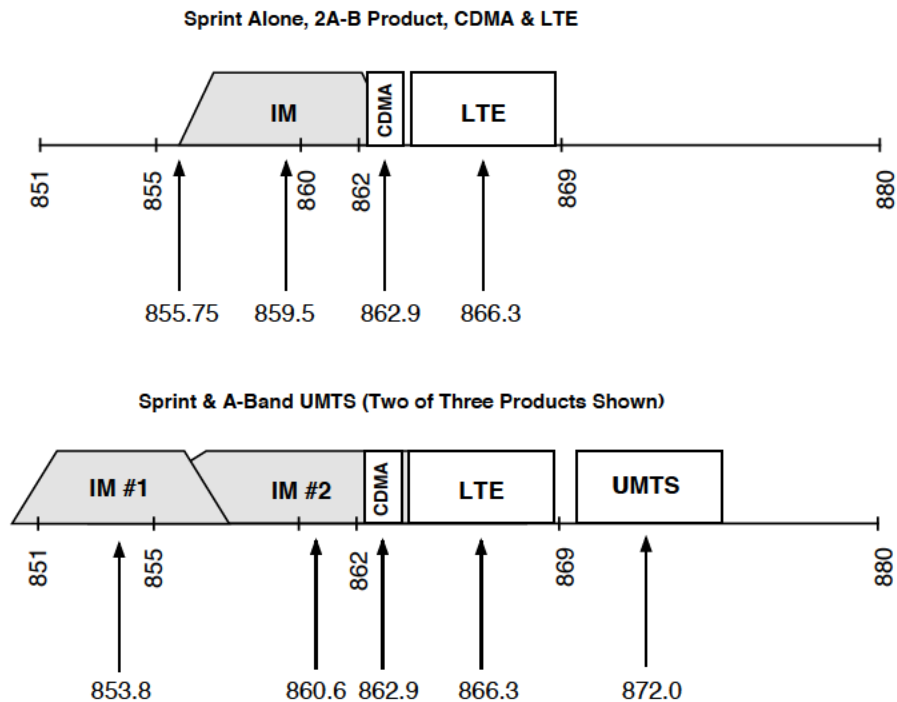


Figure 2 - 800 MHz Cellular 3rd Order Intermodulation Products (amplitude not to scale)⁷

But 900 MHz is different because there is only one proposed broadband carrier close enough to the narrowband 900 MHz users to cause IM and IM requires at least two RF carriers.⁸ The only type of two-carrier broadband IM that is likely to occur at 900 MHz are mixes between the LTE carrier and 900 MHz narrowband carriers and only if the two systems are co-located on the same tower (and roughly the same height on the tower) or rooftop. If the two systems *are* co-located there will not be a near/far problem for the subscribers of the co-located narrowband system, only potentially for other 900 MHz users operating near the co-location site and communicating with a distant repeater site. This would seem to be a rare case and one that can be mitigated or simply avoided at the time of deployment.

It is well known that a single strong interferer can cause receiver desense through an effect called *blocking*. Blocking can occur several MHz from the frequency of the desired signal and is usually measured at least +/- 1 MHz from the desired frequency. Another source of desense that

⁷ The third product in the co-location case is A+B-C type, roughly 12.25 MHz wide and centered on 857.2 MHz. In general, the bandwidth of an IM product is a function of the order of the product and is roughly equal to the sum of the products of each interferer's bandwidth and its IM product coefficient (a crude but useful approximation). The power density of these IM products is typically not uniform even if each interferer is uniform (i.e., square) because the convolution of the two signals creates a trapezoidal shape in the frequency domain.

⁸ For traditional IM. Spectral regrowth from a single broadband carrier shares many of the characteristics of IM as a consequence of the signal modulation and inherent non-linearities in the amplifier.

generally occurs at closer spacing is *spectral regrowth*. Spectral regrowth is a form of intermodulation that occurs when a modulated signal passes through a non-linearity. Another way to describe it is to recognize that any device that produces intermodulation products in the presence of two (more more) distinct carriers will inevitably produce spectral regrowth due to intermodulation in the presence of a single broadband modulated signal. If a single interferer is relatively close to the desired signal in frequency (i.e., less than +/- 1 MHz), the effect may be less blocking and more spectral regrowth.

There may be situations where the 900 MHz broadband LTE carrier creates strong signals on the street in locations where the incumbent's desired signal is weak. If the receiver cannot fully reject the unwanted signal, some receiver impairment will occur due to blocking and spectral regrowth in the receiver front end. All land mobile radios are subject to strong signal interference at one time or another, so the potential for harmful interference does not in itself preclude co-existence with a broadband LTE carrier. In fact, 800 MHz public safety users face similar strong signals every day and most modern 800 MHz radios can reject this type of interference sufficiently that performance is only rarely impaired. One measure of the impact of receiver-induced interference at 900 MHz is whether it is worse than 800 MHz interference to public safety users, a situation that is generally considered acceptable if good performing subscriber radios are used.

Like public safety 800 MHz receivers, narrowband 900 MHz receivers are better equipped to deal with a single strong interferer (blocking) than IM products of two interferers. Typically, receivers can withstand signals as high as -25 dBm before blocking occurs (as measured by the TIA-603-D method or similar).⁹ That said, the lack of a guard band at 900 MHz may potentially introduce desense that does not occur at 800 MHz, due to spectral regrowth in the receiver LNA.

To summarize, at 900 MHz there is a single broadband interferer and no guard band while at 800 MHz there are two or more broadband interferers and a 2 MHz guard band.¹⁰

3.2 The Broadband LTE Radio Carrier

The Petitioners proposed to allow deployment of 4G broadband facilities employing the 3GPP LTE standard waveform. The LTE standard supports several different bandwidths, including 1.4, 3, 5, 10, 15 and 20 MHz. The Petitioners propose a 3 MHz-wide LTE carrier which has a

⁹ Based on this firm's bench measurements of 800 MHz and 900 MHz subscriber radios.

¹⁰ For most public safety users. During rebanding, some 800 MHz public safety licensees elected to retain their frequencies in the 860-861 MHz expansion band and their guard band is only 1 MHz.

maximum occupied bandwidth of 2.7 MHz.¹¹ The LTE downlink carrier employs Orthogonal Frequency Division Multiple Access (OFDMA) and Orthogonal Frequency Division Multiplexing (OFDM). OFDM splits the LTE carrier into many subcarriers, each 15 kHz wide. Each subcarrier can operate with QPSK, 16-QAM or 64-QAM modulation, depending on the instantaneous carrier-to-noise ratio (C/N). On the uplink, LTE employs a pre-coded version of OFDM called Single Channel, Frequency Division Multiple Access (SC-FDMA). SC-FDMA has a lower peak-to-average power ratio than the downlink modulation which results in lower battery consumption.

LTE has a time-slotting characteristic similar to Time Division Multiple Access (TDMA) using 10 ms long frames with 10 subframes and each subframe having two slots of 0.5 ms each.

A resource block (RB) is the smallest unit of frequency and time that can be allocated to a user. The resource block is 180 kHz wide in frequency and 1 slot (0.5 ms) long in time. In frequency, resource blocks are 12 x 15 kHz subcarriers wide.

The 3 MHz LTE downlink carrier can support gross data rates as high as 15.1 Mbps with no antenna diversity or 60.5 Mbps with 4x4 MIMO.

LTE is normally deployed as an $N=1$ reuse scheme meaning that all sites and all sectors operate with the same radio frequency carrier. Self-interference is managed using time sharing of the channel and path loss which attenuates self-interference between the co-channel cell sites.

Subscribers share the LTE channel on a slot-by-slot basis and only one subscriber transmits in its assigned frequency segment (one or more 180 kHz-wide resource blocks) at a time. While only one broadband subscriber is transmitting in a resource block in a sector at one time, the interference present at the 900 MHz narrowband repeater is the cumulative interference from all broadband subscribers with signals above the noise floor of the narrowband receiver.¹² Further complicating the modeling problem is that the LTE subscriber radio uses power control that is a function of its distance from the LTE base station, not its distance from the affected repeater.

On the downlink, the amount of LTE OOB power captured by the narrowband receiver depends on several factors:

¹¹ The maximum occupied bandwidth is equal to the maximum number of resource blocks multiplied by the bandwidth of a resource block (180 kHz). For a 3 MHz LTE carrier, the maximum number of resource blocks is 15 and the maximum occupied bandwidth is $15 \times 180 \text{ kHz} = 2.7 \text{ MHz}$.

¹² To be more precise, a signal exactly equal to the thermal noise floor of the receiver increases the effective noise floor by 3 dB. From the point of view of the victim receiver, it is preferable that the interference be below the thermal noise floor by some amount that would make the interference impact negligible, say 1 dB. For a 1 dB impact, the interference must be 6 dB below thermal noise ($10\log_{10}(1 + 0.25) = 1.0 \text{ dB}$).

- The path loss from the LTE base station to the narrowband subscriber radio
- The LTE base station vertical antenna pattern
- The emission mask which is $55+10\log_{10}(P)$ dB in a 30 kHz bandwidth
- The equivalent noise bandwidth of the narrowband receiver

Because the emission mask requirement is relative to transmit power, the maximum allowed emission is -55 dBW or -25 dBm, independent of transmitter power. This simplifies the modeling and the analysis. Narrowband receivers designed to operate on 12.5 kHz channels (2.5 kHz max deviation for analog FM) require an equivalent noise bandwidth of 5.5 kHz for FM and P25 and 7.0 kHz for DMR [5]. In practice, manufacturers must employ wider IF bandwidths to accommodate frequency stability errors at both the base station and the subscriber unit. The additional bandwidth required can be calculated if the frequency stability of each transmitter and receiver is known [5]. To accommodate these frequency errors, manufacturers typically widen the IF bandwidth to 8.5 kHz (equivalent noise bandwidth) for 12.5 kHz channels. Because the emission mask is measured in 30 kHz, the actual power captured in the receiver's IF bandwidth is $10\log_{10}(8.5/30)$ or -5.5 dB relative to the power in 30 kHz.¹³

3.3 Potential 900 MHz Interference

Incumbent users who might be adversely affected by a 900 MHz broadband carrier fall into two categories: Part 90 narrowband users and Part 24 users. Part 90 narrowband devices are generally push-to-talk radios and the band segment edges under the Petitioners' proposal would be 898 and 937 MHz. Part 24 users at the band edges (901 and 940 MHz) are primarily Advanced Metering Infrastructure (AMI) devices for utilities, otherwise known as smart meters. The potential for interference to these two types of incumbent users is addressed in the next two sections.

4.0 Potential Interference to Part 90 Incumbents

According to the Petitioner's proposal, the PEBB licensee is obligated to provide comparable facilities following band realignment and we expect that obligation to include no loss in ERP. During the petition proceeding, commenters expressed concern that realignment will require tighter frequency spacing and therefore greater combiner loss. There are several ways to address combiner loss if it occurs: lower-loss combiners, higher gain antenna, greater transmit power, lower loss coaxial cable, or as a last resort, an additional transmit antenna (to achieve wider channel spacing in the combiner).

¹³ Assuming the out-of-band emissions approximate white noise over 30 kHz.

In contrast, FCC precedent does not require a relocating party to guarantee the absence of interference or even no greater interference than the *status quo*. Instead the FCC has traditionally followed a policy of limiting out-of-band emissions and ignoring receiver performance. Recent decisions by the FCC put more burden on the receiver without mandating specific receiver performance. In the case of 800 MHz rebanding, the FCC adopted new rules establishing minimum performance standards for victim receivers to be entitled to protection, a minimum $C/(I+N)$ the victim receiver is entitled to, and a procedure for reporting and correcting interference when it occurs [4]. More recently, the FCC created a *harm claim threshold* of interference power flux density (PFD) above which the victim licensee is entitled to protection [6]. Thus, the FCC is now placing some of interference mitigation burden on the receiver by establishing a threshold below which the receiver is expected to function. Above this threshold, the burden is on the transmitter. For the purpose of this white paper, we are not proposing a standard for comparable facilities with respect to broadband interference, rather we seek to understand and quantify potential interference and devise practical methods to reduce any actual interference to manageable levels.

As stated in Section 3.0 of this report, there are four types of interference under consideration:

- Transmitter out-of-band-emissions (OOBE)
- Receiver intermodulation (IM)
- Receiver-induced spectral regrowth
- Receiver blocking (also called receiver *overload*)

Transmitter and receiver-induced interference and transmitter combiner issues are treated separately in the following subsections. The first two subsections address the interference issue for two cases: Part 90 downlink interference at the 937 MHz segment edge and Part 90 uplink interference at the 898 MHz segment edge. The third subsection addresses the transmitter combiner concern raised by incumbents and the fourth subsection addresses downlink receiver-induced interference.

4.1 Part 90 Downlink OOBE Interference

On the broadband carrier downlink, OOBE might affect Part 90 subscriber receivers by creating a higher noise floor within the intermediate frequency (IF) bandwidth of the receiver. The Petitioners have proposed an emissions limit below 937 MHz of no greater than $55+10\log_{10}(P)$ dB below the transmit power, measured in a 30 kHz bandwidth. It is straightforward to show that this limitation is equivalent to no greater than -25 dBm in a 30 kHz bandwidth, independent of transmitter power. Most Part 90 narrowband users are limited to $43+10\log_{10}(P)$ dB which is equivalent to -13 dBm (see §90.210, emission mask I). Additional bandpass filtering can be used at the broadband base station to reduce the -25 dBm even further, if necessary. For this study, we modeled carrier-to-interference plus thermal noise ratio, $C/(I+N)$, for the -25 dBm case and

for -37 dBm and -57 dBm to represent additional filter rejection of 12 and 22 dB, respectively.

Today, Bittium offers both LTE base stations and subscriber units that meet the -25 dBm out-of-band emissions standard. Datasheets for Bittium radios are found in Appendix C.

To understand the effects of downlink OOB, we picked three typical markets to model with the goal of identifying those areas where the $C/(I+N)$ of the incumbent due to OOB is below 17 dB.¹⁴ These three markets are San Antonio, TX; Orlando, FL and San Diego, CA. The propagation software used was **EDX SignalPro™** with 30 meter terrain data and the National Land Cover Database (NLCD). The propagation model was the TSB-88.2-E Anderson 2-D diffraction model with clutter loss. This model is an industry standard and is widely accepted for land mobile radio. Broadband OOB was modeled as a co-channel emitter of -25 dBm in a 30 kHz bandwidth or -30.5 dBm in 8.5 kHz bandwidth (the IF bandwidth of the incumbent subscriber unit). Incumbent interference from all incumbent repeaters was modeled at -13 dBm -5.5 = -18.5 dBm. The actual incumbent site data and ERP were used from the ULS, assuming a typical 10 dBd gain antenna (dbSpectra Model DS9A10F36U3D).

The useable signal threshold for the incumbent subscriber was assumed to be -101 dBm on a fading channel which corresponds to a 12 dB SINAD static sensitivity of -120 dBm and a Delivered Audio Quality (DAQ) of 3.4 [4].

The broadband cell site antenna height was set at 36.6 meters (120') and the study area was arbitrarily set to a 15 mile radius. A 60 meter tile size was used for this study.

We are interested in the case where the $C/(I+N)$ in a study tile is less than 17 dB and the broadband OOB is stronger than the cumulative incumbent OOB *and* the incumbent signal is greater than -101 dBm. **EDX SignalPro™** signal amplitude data was exported to **ESRI Arcview™** to perform this analysis and produce coverage maps for each market.

An actual typical incumbent network was selected in each of the three markets for modeling the desired signal.

Figure 3 shows the $C/(I+N)$ results for San Antonio for the incumbent Lower Colorado River Authority (LCRA), a regional utility. The tiles in red correspond to $C/(I+N) < 17$ dB. They comprise 0.65% of the tiles in the 15-mile service area and are limited to a few hundred meters around each broadband cell site.

Figure 4 shows the $C/(I+N)$ results for Orlando, FL for the incumbent Duke Energy. In this case, the red tiles correspond to 0.041% of the service area.

¹⁴ The minimum $C/I+N$ set by the FCC for 900 MHz B/ILT. See FCC § 90.672(a)(1)(ii)(B).

Figure 5 shows the $C/(I+N)$ results for San Diego for the incumbent San Diego Gas & Electric (SDG&E, a subsidiary of SEMPRA). Here, the red tiles correspond to 0.11% of the service area. For San Diego, we have co-located three of the six LTE cell sites with incumbent SDG&E repeater sites. Note the absence of red tiles (indicating $C/I+N < 17$ dB) around the co-located sites.

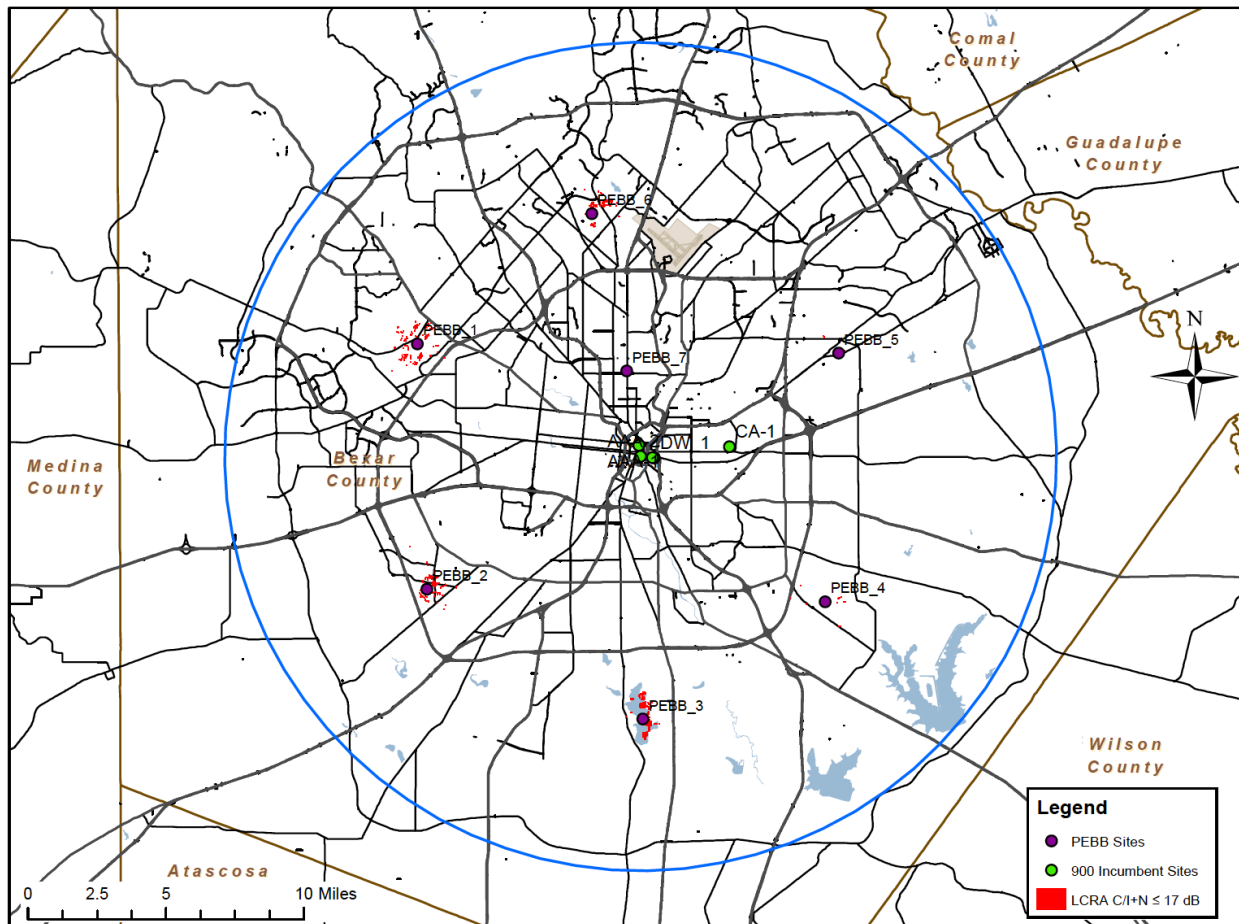


Figure 3 - Downlink OOB Impact from 7-Site Broadband Network in San Antonio (LCRA)

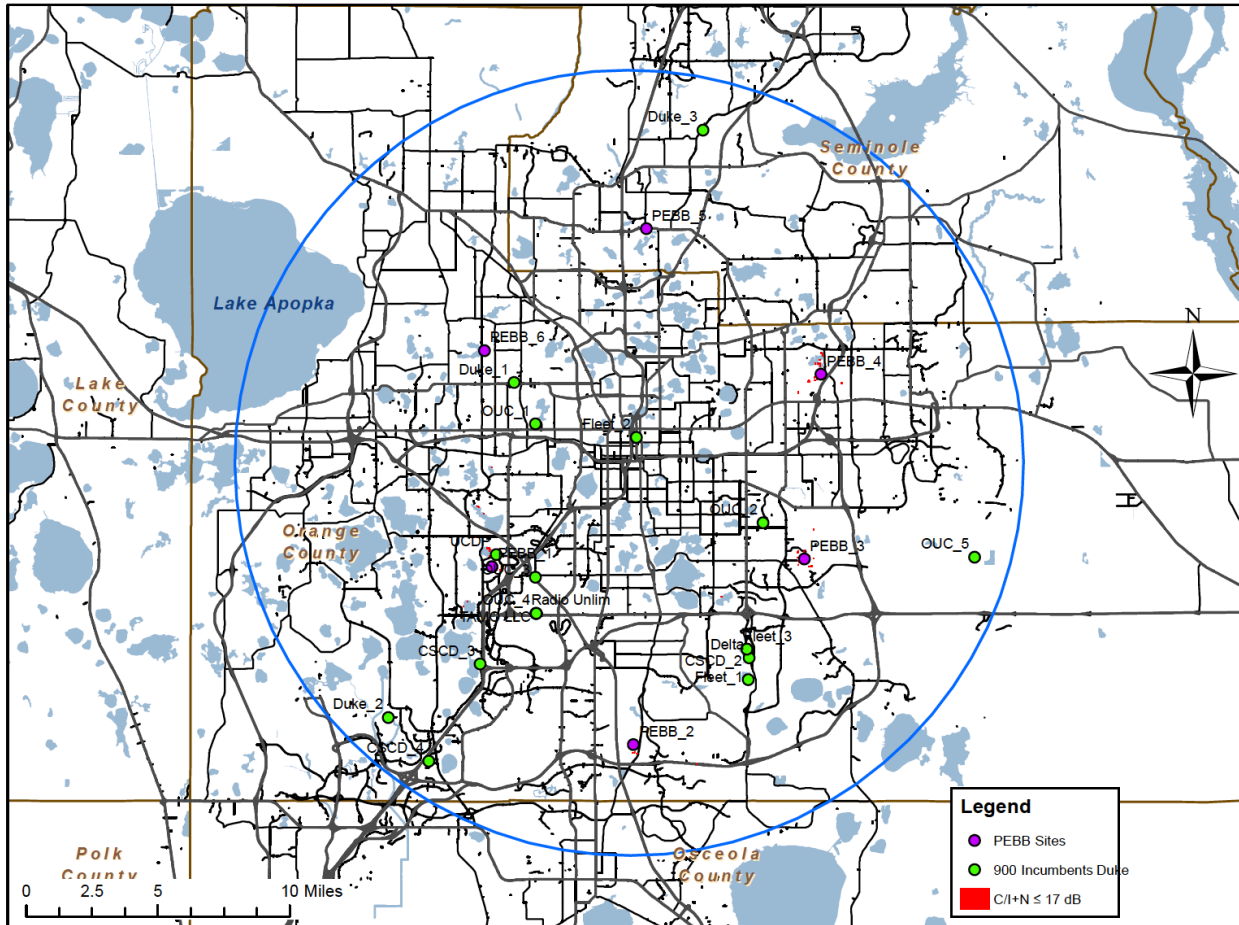


Figure 4 - Downlink OOB Impact from 6-Site Broadband Network in Orlando (Duke Energy)

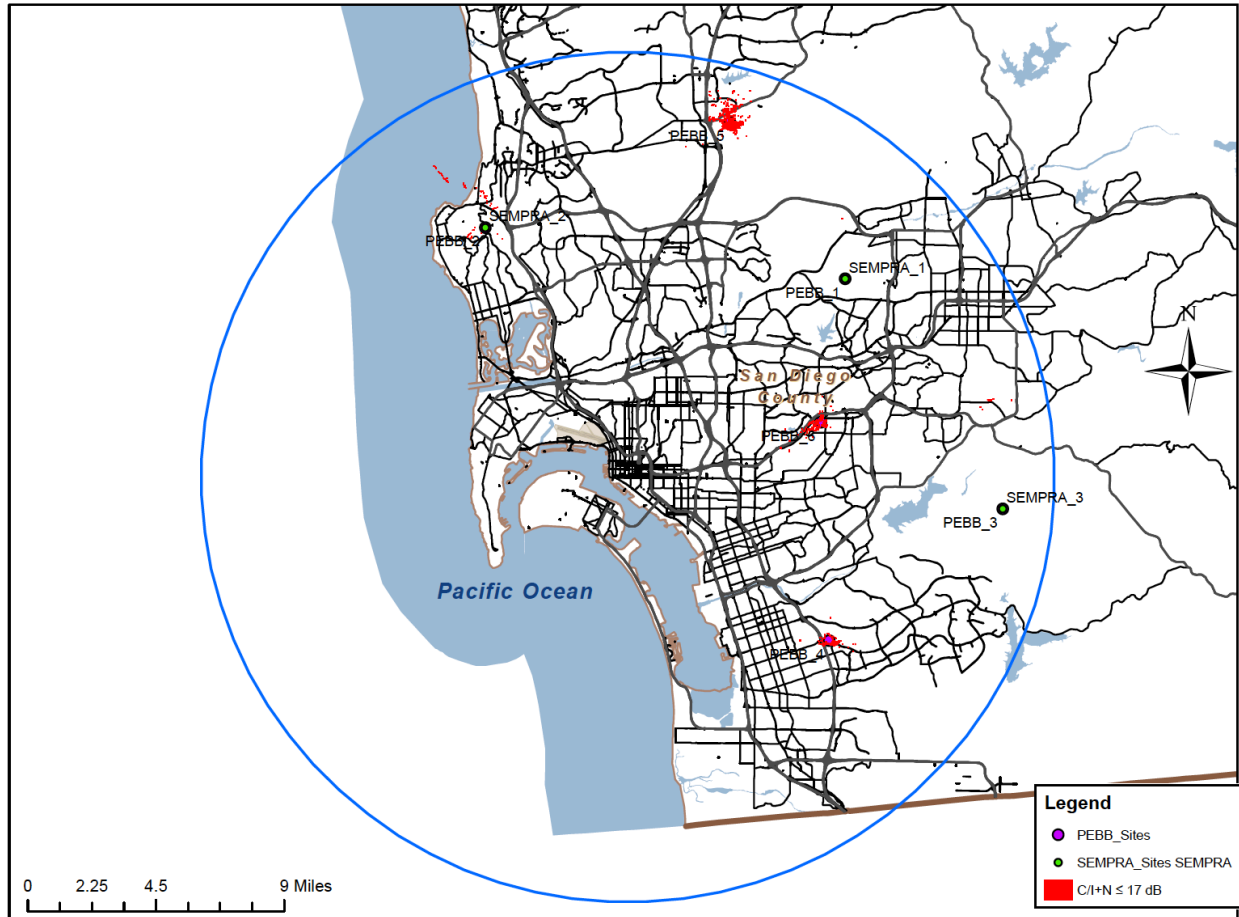


Figure 5 - Downlink OOB Impact from 6-Site Broadband Network in San Diego (SDG&E)

If interference should occur, base station filters can reduce the impact considerably as shown in Figures 6 and 7 for a 12 dB and 22 dB filter, respectively, in the San Diego market. The 12 dB filter reduces the tiles with $C/(I+N)$ less than 17 dB to 0.023% and the 22 dB filter to 0.0013%.

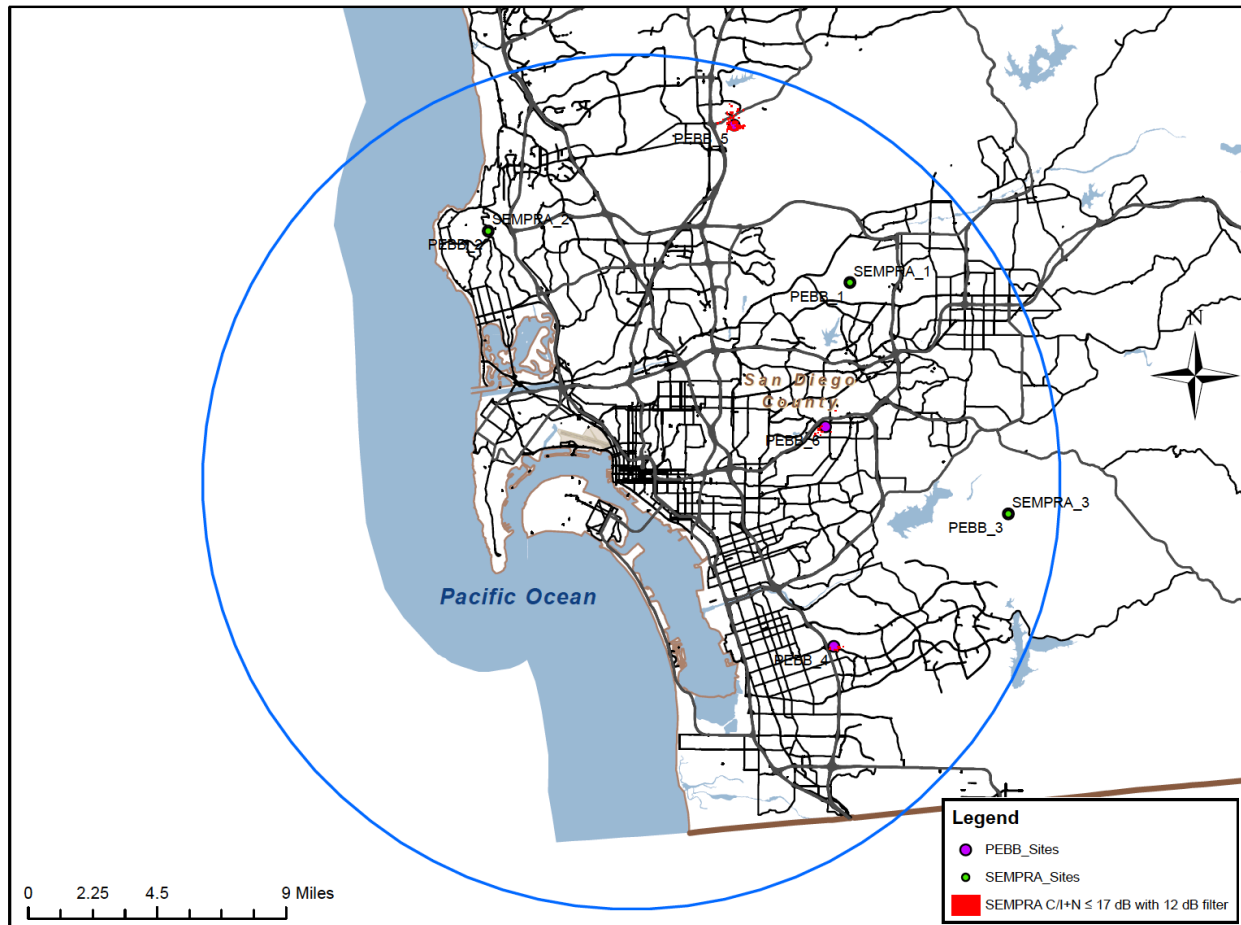


Figure 6 - Downlink OOB Impact from 6-Site Broadband Network in San Diego (SDG&E)
(12 dB Filter)

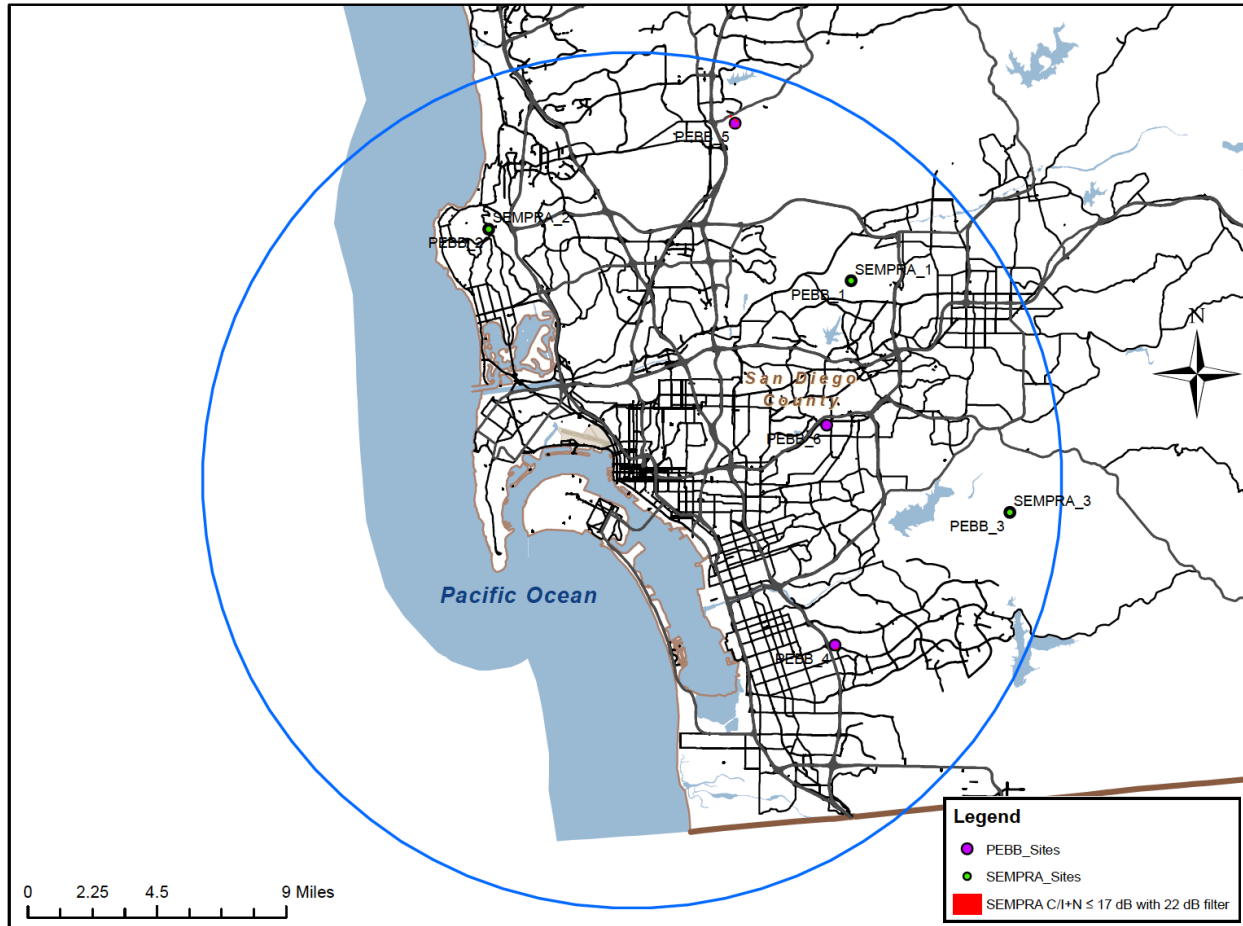


Figure 7 - Downlink OOB Impact from 6-Site Broadband Network in San Diego (SDG&E) (22 dB Filter)

Table 1 shows the effect of filters for all three markets.

Table 1 - C/(I+N) Less Than 17 dB Due to Downlink OOB				
Market	Incumbent	Area Affected	12 dB Filter	22 dB Filter
San Antonio, TX	LCRA	0.65%	0.023%	0.006%
Orlando, FL	Duke Energy	0.041%	0.00%	0.00%
San Diego, CA	SDG&E	0.11%	0.023%	0.0013%

4.2 Part 90 Uplink OOB Interference

In the uplink case, we are concerned with out-of-band emissions affecting the receiver at the Part 90 narrowband repeater. Receiver IM and blocking are non-issues on the uplink because broadband subscriber radios are low power (3 Watts or 1 Watt) and the Part 90 incumbent

repeater receive antenna is typically high on a tower. Plus, the repeater is typically more robust than a subscriber radio when it comes to IM and blocking.

Because the LTE uplink multiple access scheme is SC-FDMA, only one subscriber in each sector is transmitting in a resource block at a time. The subscriber's out-of-band emissions are also limited to -25 dBm in a 30 kHz bandwidth. This interference can be modeled.

In the worst case, the path from the broadband subscriber interferer to the repeater site is line-of-sight. If we assume a 10 dBd gain antenna at the victim repeater, a -124 dBm 12 dB SINAD sensitivity (TTA assumed), 3 Watts transmitter power, mobile antenna gain of 3 dBd, mobile cable loss of 2 dB, then the minimum path loss required to ensure no more than 1 dB desense is calculated by the following equation:¹⁵

$$L_{fs} = 137 \text{ dBm} - 25 \text{ dBm} - 2 \text{ dB} + 3\text{dBd} + 2.15 \text{ dBi} + 10 \text{ dBd} + 2.15 \text{ dBi} - 5.5 \text{ dB} = 121.8 \text{ dB}$$

For a radio frequency of 935 MHz, this free space path loss is equivalent to a range of 31 km. In practice, the victim receiver will see interference from multiple subscribers (i.e., multiple sectors) and most will have some clutter in the path (not line-of-sight), so the interference will not carry nearly as far as 31 km. To assess the uplink interference impact with any accuracy, it is necessary to use computer modeling of the path loss and a summation of the interference power using software like **Infovista™ Planet** or **EDX SignalPro™**. Also, the focus of this study is not whether or not the broadband network causes measurable interference, but whether the interference it creates results in a $C/(I+N)$ less than 17 dB at the incumbent repeater site. Thus, we care not only about potential interfering signals, but also the simultaneous amplitude of the 900 MHz incumbent mobile at the repeater site.

Recall that to model the downlink OOB case, we made a worst-case assumption that the transmitter always produced -30.5 dBm (in 8.5 kHz bandwidth), regardless of transmitter power or frequency separation. The uplink case is different than the downlink case because the LTE subscriber uses power control. Subscribers close to the cell site generally operate at lower power while subscribers far from the cell site operate at higher power. Self interference and grade of service also affect the subscriber's instantaneous power. To be 3GPP standard-compliant, an LTE mobile subscriber must reduce its out-of-band emissions by at least 1 dB for every 1 dB reduction in power from maximum [10]. For our purposes, we assume that the maximum allowed OOB of -30.5 dBm occurs at full power. A CSMAC study [11] shows that 98.3% of the time, the transmit power of an LTE subscriber is backed off at least 9 dB. Thus, it is

¹⁵ We assume the receiver requires a C/N of 7 dB to achieve 12 dB SINAD [5], so the thermal noise floor is $-124 - 7 = -131$ dBm and the level that creates a 1 dB impact is $-131 - 6 = -137$ dBm. 2.15 dBi is the gain of a dipole. The factor of -5.5 dB accounts for the difference between the IF bandwidth of 8.5 kHz and the measurement bandwidth of 30 kHz.

reasonable to model the LTE subscriber as an interfering emitter transmitting at $-30.5 - 9 = -39.5$ dBm.

To model uplink interference at the incumbent repeater site and $C/(I+N)$, we first assumed that a single LTE subscriber is equally likely to be located anywhere in the 15-mile radius service area. At each study tile in the service area, the subscriber is modeled as an interference source operating at -39.5 dBm. We then used **EDX SignalPro™** to calculate the interference level created at the repeater site from an interfering LTE subscriber at each of n study tiles. Assuming a 24.3 km (15 mile) study radius and 800 meter tiles, $n = 2,899$. Tiles with associated levels less than -137 dBm were filtered out of the sample set. Thermal noise power of -131 dBm (in 8.5 kHz) was added to each interference sample to get $I+N$.

The incumbent mobile is also equally likely to be anywhere in the service area, independent of the location of the LTE subscriber. Similarly, we calculated the incumbent mobile signal level at the repeater site from each of the 2,899 tiles. We then filtered out any tiles resulting in signals less than -105 dBm (our threshold for acceptable service on a fading channel).

We now want to compute the value of $C/(I+N)$ in dB for all possible combinations of incumbent signal and interference value. If there are n tiles in the study area, the number of $C/(I+N)$ pairs can be as high as n^2 which for our 15-mile study area is over 8.4 million pairs. The probability that a pair has $C/(I+N) < 17$ dB is estimated by dividing the number of pairs with value less than 17 dB by all pairs resulting from the two sample sets (maximum of n^2). This large sample size makes it impractical to consider all permutations of location for 18 or 21 LTE subscribers. Instead, we model a single LTE subscriber and weight this subscriber by a conservative factor to account for multiple simultaneously transmitting subscribers.

We know that there can be as many as 18 (6 LTE sites) or 21 (7 LTE sites) simultaneously transmitting LTE subscribers in the service area, but it is likely that no more than three of these can cause harmful interference based on a simple geometric argument that no more than three sectors are close enough to the incumbent repeater site to cause measurable interference. To test this theory, we weighted the single interferer by a factor of 2, 3 and 9 to see if there were any cases of more than three sectors creating harmful interference. In all three markets, a maximum of two sectors created harmful interference, so we conservatively selected a weighting of 3 or 4.8 dB.

The following study parameters were used in **EDX SignalPro™**:

- Mobile antenna height for incumbent and LTE subscriber = 1.6 m
- Incumbent subscriber transmit power = 3 W
- Incumbent subscriber antenna gain = 0 dBi
- LTE subscriber antenna gain = 0 dBi

LTE subscriber OOBE = -25 dBm measured in 30 kHz, -30.5 dBm in 8.5 kHz

Handset backoff = 9 dB

Propagation model = TIA-TSB-88.2-E [6]

Minimum useable incumbent signal = -105 dBm

Study tiles = 2,899

Incumbent receiver noise floor = -131 dBm

Threshold of LTE interference for *de minimis* harm = -137 dBm

Figure 8 shows all the 800 meter interference tiles that when paired with at least one 900 MHz incumbent mobile tile resulted in $C/(I+N) < 17$ dB for the Orlando, FL market for incumbent Duke Energy. Note there are a total of only five harmful interference tiles and all are very close to the incumbent repeater site. While there are only five interference tiles, there are many incumbent mobile tiles associated with each interfering tile. In fact, there are an average of 73 incumbent mobile tiles paired with each LTE interfering tile. For clarity of presentation, the corresponding incumbent tiles are not shown in Figure 8. Similar plots for San Antonio, TX and San Diego, CA are found in Appendix A.

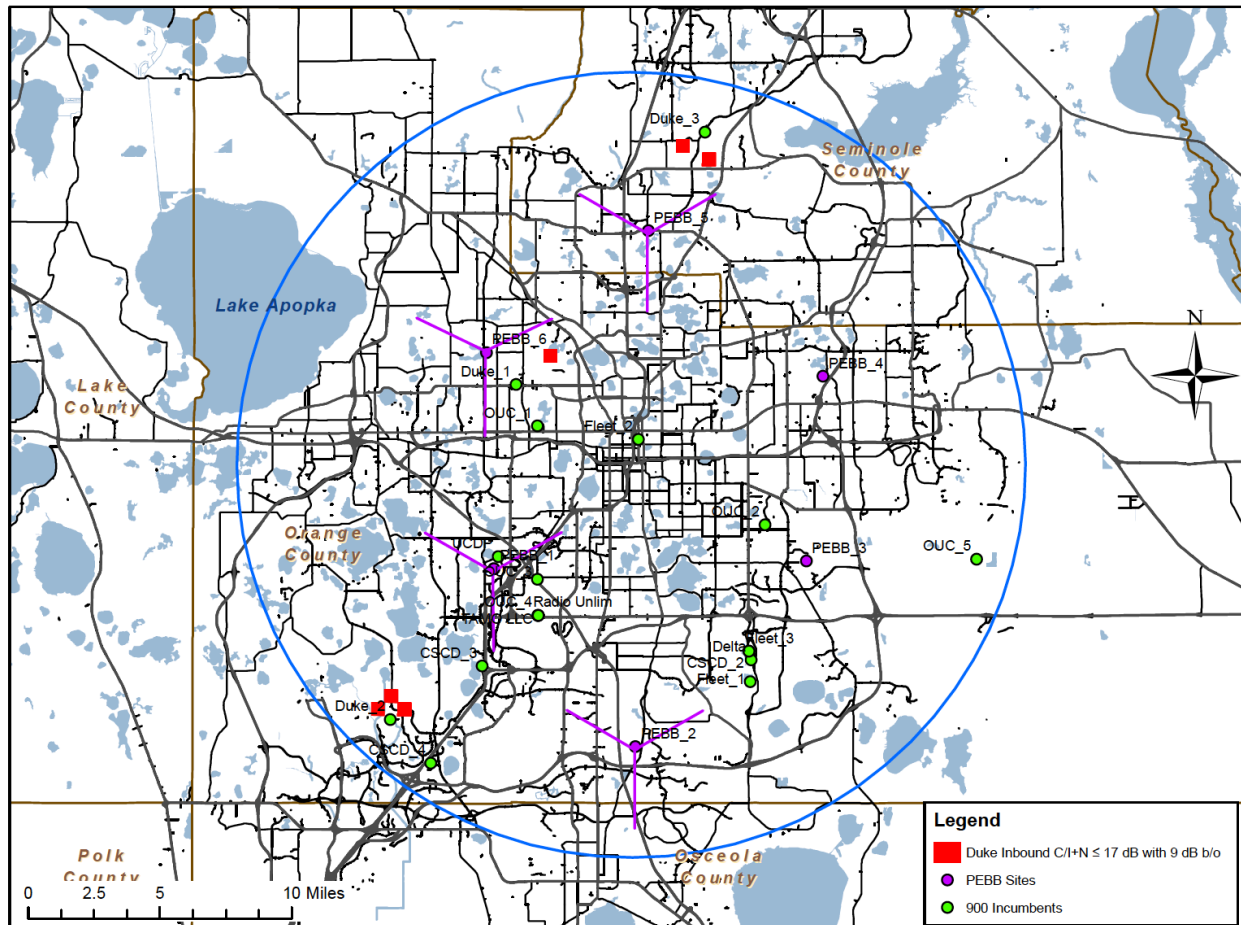


Figure 8 - LTE Uplink Interference to Duke Energy 900 MHz Sites (9 dB backoff)

The uplink interference results for each of three study markets are shown in Table 2. Note that the probability of harmful uplink interference is quite small in all three markets, much less than 1%.¹⁶

Table 2 - C/(I+N) Less Than 17 dB Due to Uplink OOB		
Market	Incumbent	P(C/(I+N)) < 17 dB
San Antonio, TX	LCRA	0.041%
Orlando, FL	Duke Energy	0.025%
San Diego, CA	SDG&E	0.0015%

4.3 Part 90 Transmitter Combiner Issues

Another area of concern for the incumbents is that the new facility must match the ERP of the old facility and this may be difficult to do if channels are packed more closely in the transmitter combiner, thereby creating more insertion loss.

While it is true that tighter channel spacings generally result in greater insertion loss in cavity-ferrite transmitter combiners, it is not clear at the time of this writing whether tighter spacings will actually be required or not. There are too many unknown variables such as how many incumbents must be accommodated in the 2x2 MHz segment (some may elect to move to the broadband service or to another band or service entirely). It is clear, however, there are several effective ways to mitigate the problem:

- According to dBspectra, a leading vendor of transmitter combiners, modern ceramic cavity filter combiners have at least 1 dB less loss than older combiners like the popular DB8062G for the same frequency spacing [12]. See Figure 9.
- Combiner losses, if they occur, can be made up with higher transmit power (in some cases), greater antenna gain (in some cases) or lower loss coaxial cable (e.g., LDF-7, 1-5/8" diameter versus LDF-5, 7/8" diameter).
- As a last resort, the incumbent's channels can be split between two combiners (and antennas) to achieve greater frequency spacing.

¹⁶ We believe that even these small values are conservative meaning they over-predict the likelihood of interference. In over 15 years of investigating 800 MHz interference at public safety repeater sites, the author has not encountered one case that could be attributed to cellular subscriber out-of-band emissions.



Figure 9 - dB Spectra Bandpass Filter Response (Blue) vs. Legacy Filter (Red) [12]

The FCC addressed this same issue when considering limited 800 MHz replacement capacity in Canadian Border Regions and reached the following conclusion:¹⁷

“We recognize that assigning replacement channels to non-ESMR licensees in the manner described above will reduce the potential separation between the upper and lower bounds of available frequencies in the non-ESMR pool, which may require some non-ESMR licensees to make use of more efficient combiners in order to compensate for decreased frequency separation. We note that where more efficient combiners are required for this reason, Sprint must pay the reasonable cost of such combiners under its obligation to provide relocating licensees with comparable facilities.”

4.4 Part 90 Downlink Receiver-Induced Interference

The Petitioners proposed a realignment of the 900 MHz band without a guard band between the broadband LTE carrier and narrowband incumbents. It’s not automatic that a guard band would eliminate receiver-induced interference, especially because the incumbent receiver has no filter to exploit a guard band and passes the entire 935-940 MHz band. Thus, the broadband carrier will appear at the incumbent receiver LNA with no attenuation (other than an AGC attenuator if one is present). Thus, it is likely that blocking, spectral regrowth or some other impairment will occur and desense the receiver, even if the LTE transmitter is emitting a pristine signal (no OOB).

¹⁷ Improving Public Safety Communications in the 800 MHz Band, WT Docket No. 02-55, *Second Report and Order*, 23 FCC Rcd 7605 at ¶19 (2008).

The receiver is a complex system that is difficult to model accurately, so measurements are the best way to characterize receiver performance in the presence of a strong LTE interferer. Bench measurements treat the receiver as a black box and no knowledge of the precise interference mechanism is required. Instead, we simply measure the ability of the receiver to reject the interferer. The resulting Strong Signal Interference (SSI) rejection is simply the difference in dB between the amplitude of the interfering LTE signal and the amplitude of the desired signal required to achieve the minimum level of performance, in our case 12 dB SINAD. The receiver *desense* is defined as the difference in dB between this amplitude of the desired signal and the receiver sensitivity. For example, consider a receiver with measured sensitivity of -120 dBm operating in the presence of an interferer with amplitude -30 dBm. If the receiver has measured SSI rejection of 75 dB at this interferer amplitude, then the desense is $-30-75-(-120) = 15$ dB. But as long as the receive signal at that location exceeds -105 dBm (static), the receiver is unaffected.

Thus, the measure of goodness for a 900 MHz subscriber radio is not simply the presence or absence of desense. All land mobile radio systems have geographic areas where desense occurs, most often by blocking or receiver IM in the near/far scenario previously discussed. For example, 800 MHz public safety receivers often experience some desense when near 800 MHz cell sites because the receiver front end filter passes frequencies in the cellular band, but as long as the desired signal is sufficient to overcome it, subscriber radio performance is unaffected. Toward that end, there are good performing radios and poor performing radios in this scenario and the good performing radios rarely experience problems because the strong signal interference rejection is high (70 dB or more) even in the presence of very strong interferers.

We know from practical field experience that good performing 800 MHz radios operate trouble-free in virtually all locations despite the presence of strong 800 MHz cellular signals. The Motorola APX-6000/7000, Harris XG-75PE and Tait TP9400 have been measured independently by our firm and are examples of good performing radios. If typical 900 MHz radios perform equally well in the presence of a single LTE carrier, then we can conclude that receiver desense is a manageable problem at 900 MHz.

For this study, Pericle measured SSI rejection of three typical 900 MHz subscriber radios:

- Motorola XPR-6580 (analog FM and DMR)
- Motorola XPR-7580 (analog FM and DMR)
- Motorola APX-4000 (analog FM and P25)

The radios were first bench tested for sensitivity (12 dB SINAD), intermodulation rejection and blocking rejection in accordance with TIA-603-D. Then the radios were tested for SSI rejection using an LTE carrier as the interfering signal. Because our benchmark for acceptable performance is the 800 MHz interference scenario, we also tested each radio under a 900 MHz

equivalent scenario with a 1.25 MHz CDMA carrier and a 5 MHz LTE carrier spaced at the same separation as the 800 MHz band. The single 3 MHz LTE carrier performance and the 800 MHz emulation were plotted and compared to determine if the 900 MHz is worse or better than the more familiar 800 MHz scenario. A spectrum analyzer trace of the 800 MHz scenario at 900 MHz is shown in Figure 10.

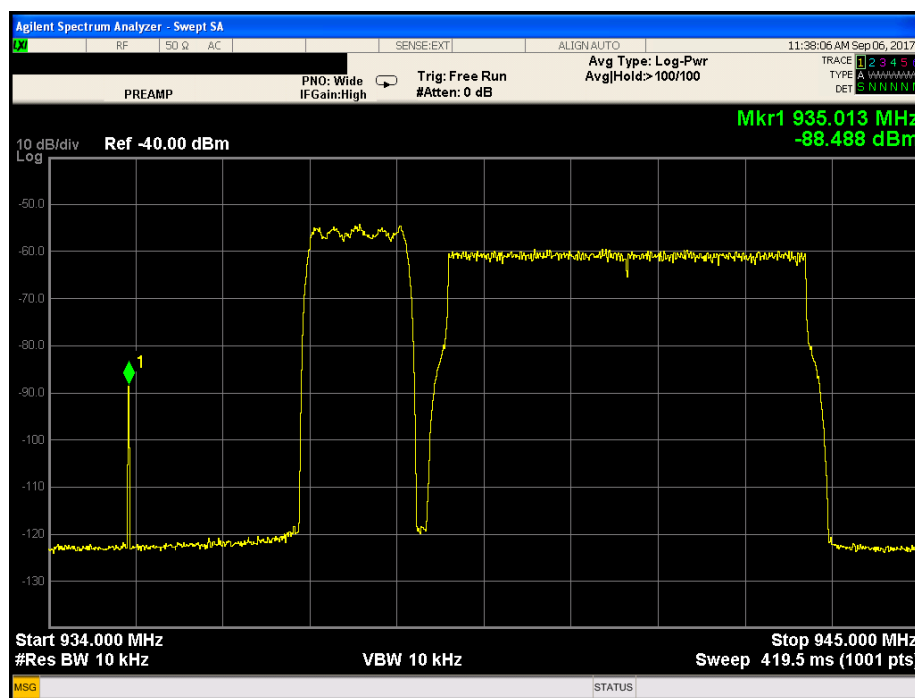


Figure 10 - 800 MHz Scenario at 900 MHz (equal power interferers)

Subscriber radios were tested in accordance with the test plan found in Appendix B to this white paper. The TIA-603-D test results for each radio are found in Table 3. The values in Table 3 are for Channel 159, 936.9875 MHz. Blocking rejection was measured at +/- 1 MHz separation.

Table 3 - TIA-603-D Test Results for 900 MHz Subscribers			
Radio	Sensitivity (dB)	IM Rejection (dB)	Blocking Rejection (dB)
XPR-6580	-120.2	76.7	99.7
XPR-7580	-121.8	78.8	101.3
APX-4000	-121.2	77.7	101.7

The XPR-6580 and the APX-4000 both include an RF AGC feature with three optional settings: Disabled, Standard and Enhanced. These radios were set to “Standard” for these measurements. The SSI rejection performance for the XPR-6580, XPR-7580 and APX-4000 are found in

Figures 11, 12 and 13, respectively. Note that the 800 MHz scenario is also plotted in each case.

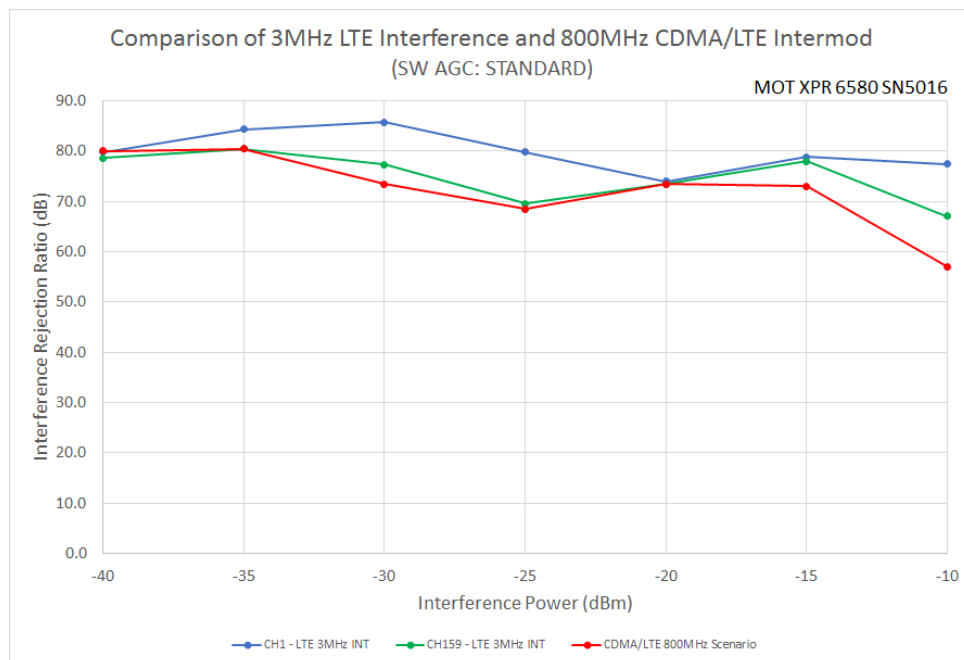


Figure 11 - XPR-6580 SSI Rejection

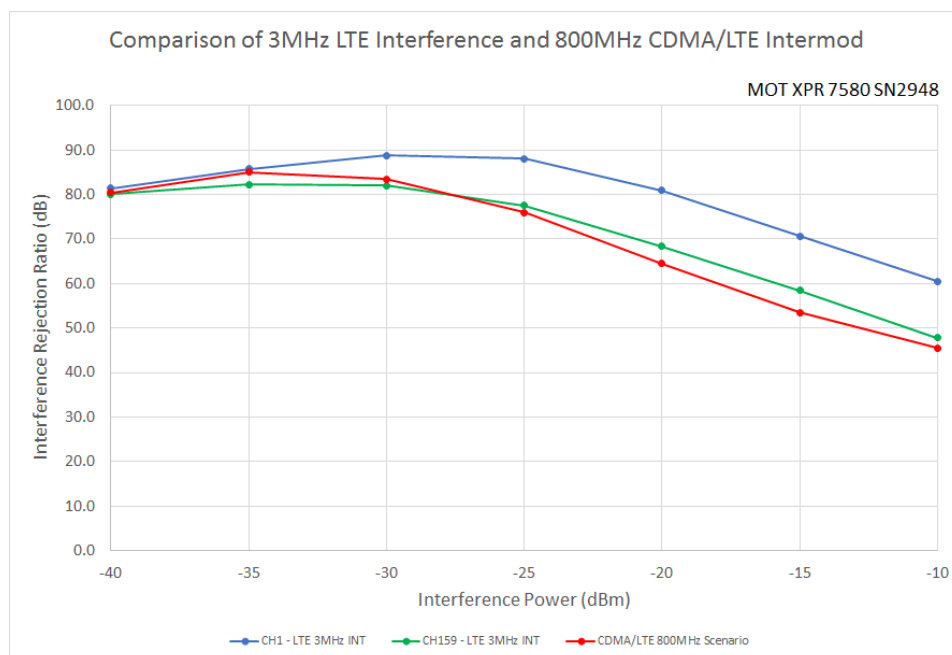


Figure 12 - XPR-7580 SSI Rejection

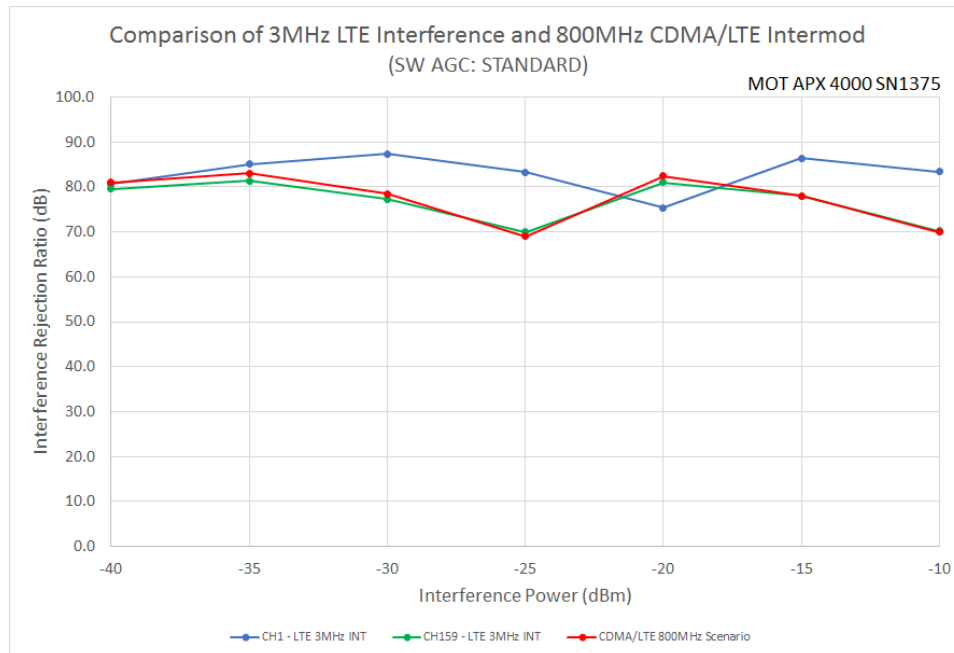


Figure 13 - APX-4000 SSI Rejection

These four plots reveal some interesting results. First, Channel 1, which is nearly 2 MHz from the broadband segment edge, shows better performance than Channel 159 which is only 12.5 kHz from the broadband segment edge. This behavior is expected if the interference is spectral regrowth as this type of interference tends to roll off with greater frequency separation. More important is the performance of Channel 159 relative to the 800 MHz scenario. For every radio tested and for almost all samples, the 900 MHz scenario performance (3 MHz LTE carrier) matches or exceeds the 800 MHz scenario performance. In other words, the 900 MHz incumbent subscriber, who has no guard band, faces an interference situation that is no worse (and in some cases better) than the 800 MHz user who benefits from a 2 MHz guard band. If the 800 MHz scenario is acceptable to public safety users for good performing radios, then the 900 MHz scenario proposed by the Petitioners should also be acceptable for good performing radios. The XPR-6580, XPR-7580 and APX-4000 are good performing radios by industry standards.¹⁸

Beyond these results, it is interesting to note that the XPR-6580, an older model, outperforms the XPR-7580. The superior performance of the XPR-6580 is probably due to its software RF AGC feature which the XPR-7580 lacks. The APX-4000 also offers an advanced RF AGC feature and its superior performance is demonstrated at the highest interferer amplitudes. This feature is not

¹⁸ At 800 MHz, good performing radios include the APX-6000, APX-7000, APX-4000, Harris XG-75PE and Tait TP9400. The measure of a good performing radio in the presence of Strong Signal Interference (SSI) is its ability to operate impact-free under typical urban conditions. A rule of thumb is the radio should operate with at least 60 dB SSI rejection for interfering power levels from -40 to -13 dBm (equivalent to 3,000 $\mu\text{W}/\text{m}^2$, see Appendix D for derivation). Based on our field experience, radios that perform at this level rarely experience problems from SSI.

widely known in the industry, *but it is important that 900 MHz subscriber radios be programmed to activate this feature.*

5.0 Potential Interference to Part 24 Incumbents ---

FCC Part 24 governs the 901-902, 940-941 MHz band, known as the Narrowband PCS (NPCS) band. Sensus Metering Systems is an AMI manufacturer whose equipment operates in this band. During the petition proceeding, Sensus provided a document with many of its relevant base station radio specifications [9]. The Sensus system employs thousands of fixed metering units (subscribers or *endpoints*) and several collection points (base stations or *Tower Gateway Base Station, TGB*). The Sensus base station has sensitivity, bandwidth and blocking specifications similar to a high-performing land mobile radio repeater.

Because the Part 24 band is primarily licensed by market rather than by site, Sensus is not required to disclose the locations of its collection sites and it is not possible to model its network as we did for Part 90 users in San Antonio, Orlando and San Diego. However, if the endpoints are similar to land mobile radios, the conclusions are likely to be the same as for Part 90 incumbents.

Sensus must already operate in the presence of high power Part 90 incumbents so the only relevant question is how does the broadband system differ from Part 90 incumbents? We know the worst case OOB is actually lower than incumbents (-25 dBm versus -13 dBm), but it is possible that the PEBB licensee will employ a greater number of cell sites and that the average antenna height may be lower. So, downlink potential interference might be greater unless additional filtering is used. This is the same conclusion we reached for Part 90 incumbents.

In many ways the Part 24 interference problem is symmetrical to the Part 90 incumbent problem so the same mitigation techniques for downlink interference apply: filtering, suppressed sidelobe antenna patterns and co-location.

Similarly for uplink interference, if the collection points are located at high points like the Part 90 repeater sites, uplink interference from LTE subscribers should be low and manageable.

6.0 Proposed Rules in FCC Part 90 ---

Ensuring incumbent Part 90 and Part 24 users can successfully operate in the presence of a broadband 900 MHz carrier is a two-part process: The first part is to impose limitations on the broadband transmitter to preclude interference in the vast majority of cases (primarily through the emission mask and a maximum power flux density on the ground). The second part is to

create rules to resolve interference problems in the rare cases when they occur. The strongest precedents for such rules are § 90.672 and recently adopted § 22.913 which address interference to narrowband 800 MHz users from cellular 800 MHz base stations. Accordingly, we propose the following regulatory language:

Subpart S—Regulations Governing Licensing and Use of Frequencies in the 806-824, 851-869, 896-901, and 935-940 MHz Bands

§90.672. Unacceptable interference to non-cellular 800 MHz licensees from 800 MHz cellular systems or part 22 Cellular Radiotelephone systems, and within the 900 MHz Business/Industrial Land Transportation Pool.

Change (a)(1)(i)(A) to:

(A) A median desired signal strength of –104 dBm or higher if operating in the 800 MHz band, or a median desired signal strength of ~~–88~~ **–98** dBm if operating in the 900 MHz B/ILT Pool, as measured at the R.F. input of the receiver of a mobile unit; or ...

Change (a)(1)(i)(B) to:

(B) A median desired signal strength of –101 dBm or higher if operating in the 800 MHz band, or a median desired signal strength of ~~–85~~ **–95** dBm if operating in the 900 MHz B/ILT Pool, as measured at the R.F. input of the receiver of a portable i.e., hand-held unit; and either ...

(b) [no change]

Add the following paragraphs to Part 90 in the appropriate subparts that create the PEBB service:¹⁹

(a) *Power limitations*.²⁰

(1) Broadband Fixed and Base Station power spectral density (PSD) in the 935-940 MHz band are limited as follows:

(a) 400 W/MHz ERP in non-rural areas, and 800 W/MHz ERP in rural areas, without a power flux density (PFD) requirement.

(b) Higher PSD limits. To ensure flexibility in the deployment of broadband service beyond the ERP limits outlined in (1)(a) that would limit coverage and potential inability to deliver broadband services, broadband operators would be allowed, with the PFD rules outlined in (1)(d) to deploy at PSD levels outlined in (1)(c). A five year sunset timeframe would allow for the evolution and adoption of

¹⁹ The author understands that additional rules are needed to establish the PEBB service. The proposed rules herein are intended to address the narrower issues of co-existence with narrowband incumbents, prevention of harmful interference and remedies for the incumbent should harmful interference occur.

²⁰ To harmonize with FCC § 22.913 (800 MHz Cellular Radiotelephone Service).

narrowband LMR technologies that enable operations adjacent to broadband systems without a PFD limit.

(c) Higher power broadband rules: up to 1000 W/MHz ERP in non-rural areas, and up to 2000 W/MHz ERP in rural areas with a five year PFD limit and an advance notification requirement.

(d) Higher power broadband PFD limit of $3,000\mu\text{W}/\text{m}^2$ not to be exceeded over 98 percent of the served area within 1 km of the base station as measured 1.6 meters above ground.

(2) PEBB Control and Mobile Stations operating in the 896-901 MHz band up to 10W ERP.

(3) PEBB Portable stations operating in the 896-901MHz band up to 3W ERP.

(b) *Emission mask requirements for 900 MHz broadband fixed stations.* For any frequency below 937 MHz and above 940 MHz, the power of any emission shall be attenuated below the transmitter power (P) in watts by at least $50+10\log_{10}(P)$ decibels measured in a 100 kHz bandwidth.

(c) *Emission mask requirements for 900 MHz broadband mobile subscriber stations.* For any frequency below 898 MHz and above 901 MHz, the power of any emission shall be attenuated below the transmitter power (P) in watts by at least $50+10\log_{10}(P)$ decibels measured in a 100 kHz bandwidth.

(d) *Advance notification requirement for 898-901 MHz/937-940 MHz broadband service.* At least 30 days but not more than 90 days prior to activating a broadband cell site permitted under paragraph (xx) of this section, the broadband licensee must provide written advance notice to any Part 90 B/ILT and SMR MTA licensee authorized in the frequency range 896-898 MHz/935-937 MHz or Part 24 licensee authorized in the frequency range 901-902 MHz/940-941 MHz with a fixed site (or market edge for market-based licensees) located within a radius of 113 km of the broadband base station to be deployed. The written notice shall be required only one time for each such broadband cell site and is for informational purposes only; the 900 MHz or Part 24 narrowband licensees are not afforded the right to accept or reject the activation or to unilaterally require changes in the operating parameters. The written notification must include the base station's location, ERP, height of the transmitting antenna's center of radiation above ground level, and the timeframe for activation, as well as the PEBB licensee's contact information. Additional information shall be provided by the PEBB licensee upon request of a 900 MHz or Part 24 narrowband licensee required to be notified under this paragraph.

7.0 Conclusions and Recommendations

The purpose of this white paper is to characterize the potential technical impacts of a 900 MHz realignment and to clearly explain industry best practices, commercially available equipment, and suggested methodologies that can be applied to enable existing narrowband licensees to be relocated to the 2x2 MHz segment while maintaining or improving their existing system performance.

Both transmitter out-of-band emissions and receiver-induced interference were modeled and analyzed.

To understand the effect of out-of-band emissions, we modeled 900 MHz incumbent desired signals from actual sites and hypothetical broadband LTE interference from a prospective network. Three markets were modeled: San Antonio, TX; Orlando, FL and San Diego, CA. For broadband downlink interference, we found that out-of-band emissions resulted in $C/(I+N)$ less than 17 dB (an FCC minimum standard) in a small number of study tiles (less than 1%), in all three markets.

In the rare case where harmful downlink interference might occur, the PEBB provider should consider four mitigations to address this potential problem:

- Avoid siting broadband antennas close to the ground
- Co-locate the broadband cell site with the incumbent when possible
- Employ broadband cell site antennas with suppressed sidelobes
- Install bandpass cavity filters with greater rejection outside the 3 MHz segment

If practical, we recommend the use of 12 dB or 22 dB rejection cavity filters and suppressed sidelobe antennas as these techniques should reduce downlink interference cases to a small and manageable number.

Uplink out-of-band emissions interference is also a potential problem, but characterizing it with any accuracy is more difficult due to limitations of modeling tools, limited computing power, difficulty modeling power control effects and the basic physics of the problem. Despite these hurdles, we were able to model uplink interference and estimate the number of cases where the $C/(I+N)$ at the Part 90 repeater site is less than 17 dB. We found that in all three markets, much less than 1% of the service area was affected, a similar result to the downlink interference case.

Receiver-induced interference rejection (from blocking and spectral regrowth) was measured on the bench for four typical 900 MHz subscriber radios. We found that performance is no worse than the well-known 800 MHz case which is generally considered acceptable provided good performing radios are used. This is an interesting and far-reaching result because performance at 900 MHz with a single LTE carrier and no guard band is as good as performance at 800 MHz with two broadband carriers and a 2 MHz guard band. For radios with an RF AGC feature, it is important that this feature be turned on.

We also recommend that the FCC adopt language similar to that adopted in the 2004 800 MHz rebanding rulemaking [4] and the more recent 800 MHz cellular band ERP rulemaking [8] to protect incumbents from interference and to provide remedies when interference occurs. Specific rule language is proposed in Section 6.0 of this report.

8.0 References

- [1] Petition for Rulemaking of the Enterprise Wireless Alliance and Pacific Datavision, Inc., RM-11738 (filed Nov. 17, 2014).
- [2] Wireless Telecommunications Bureau Seeks Comment on Enterprise Wireless Alliance and Pacific Datavision, Inc. Petition for Rulemaking Regarding Realignment of 900 MHz Spectrum, Public Notice, RM-11738, , November 26, 2014 (terminated on August 4, 2017).
- [3] FCC Technological Advisory Council, Interference Limits Policy, “The use of harm claim thresholds to improve the interference tolerance of wireless systems,” White Paper, February 6, 2013.
- [4] Improving Public Safety Communications in the 800 MHz Band, Consolidating the 900 MHz Industrial/Land Transportation and Business Pool Channels, Report and Order, Fifth Report and Order, Fourth Memorandum Opinion and Order, and Order, WT 02-55, FCC 04-168, August 6, 2004.
- [5] TIA TSB-88.1-D, “Wireless Communications Systems — Performance in Noise and Interference-Limited Situations, Part 1: Recommended Methods for Technology-Independent Performance Modeling,” April, 2012.
- [6] TIA TSB-88.2-E, “Wireless Communications Systems — Performance in Noise and Interference-Limited Situations, Part 2: Propagation and Noise,” January, 2016.
- [7] TIA TSB-88.3-D, “Wireless Communications Systems — Performance in Noise and Interference-Limited Situations, Part 3: Recommended Methods for Technology-Independent Performance Verification,” October, 2013, Addendum 1, February 2017.
- [8] FCC Second Report and Order, Report and Order, and Second Further Notice of Proposed Rulemaking, WT Docket No. 12-40, March 2, 2017.
- [9] Sensus Metering Systems, “Flexnet System Details.”
- [10] 3GPP TSG-RAN4 #59AH, R4-113745, B26 Uplink LTE UE to PS BS co-existence, Bucharest, Romania, 27th June to 1st July, 2011.
- [11] Commerce Spectrum Management Advisory Committee (CSMAC) Final Report: Working Group 1 – 1695-1710 MHz Meteorological-Satellite, Appendix 3: Baseline LTE Uplink Characteristics, January 22, 2013.

[12] dB Spectra TechBook series, “RF Filters,” Figure 9.

[13] Review of the Commission’s Rules Governing the 896-901/935-940 MHz Band, Realignment of the 896-901/935-940 MHz Band to Create a Private Enterprise Broadband Allocation, Amendment of the Commission’s Rules to Allow for Specialized Mobile Radio Services Over 900 MHz Business/Industrial Land Transportation Frequencies, Notice of Inquiry, FCC 17-108, WT Docket 17-200, August 4, 2017.

9.0 Acronyms

3GPP	3rd Generation Partnership Project (a standards committee)
AES	Advanced Encryption Standard
AGC	Automatic Gain Control
AGL	Above Ground Level
AMI	Advanced Metering Infrastructure
AMSL	Above Mean Sea Level
APCO	Association of Public Safety Communications Officers
AWGN	Additive White Gaussian Noise
BDA	Bi-Directional Amplifier
BER	Bit error rate
CDMA	Code Division Multiple Access
CII	Critical Infrastructure Industry
CPC	Channel Performance Criterion
CSMAC	Commerce Spectrum Management Advisory Committee
DAQ	Delivered Audio Quality
dB	Decibel
dBi	Decibels relative to isotropic (for antenna gain)
dBd	Decibels relative to a half-wave dipole (for antenna gain)
dBm	Decibels relative to a milliwatt
DMR	Digital Mobile Radio
EIRP	Effective Isotropic Radiated Power
ENBW	Equivalent Noise Bandwidth
ERP	Effective Radiated Power (relative to half-wave dipole)
ESMR	Enhanced Specialized Mobile Radio
EWA	Enterprise Wireless Alliance
FCC	Federal Communications Commission
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
GHz	Gigahertz (10 ⁹ cycles per second)
GPS	Global Positioning System

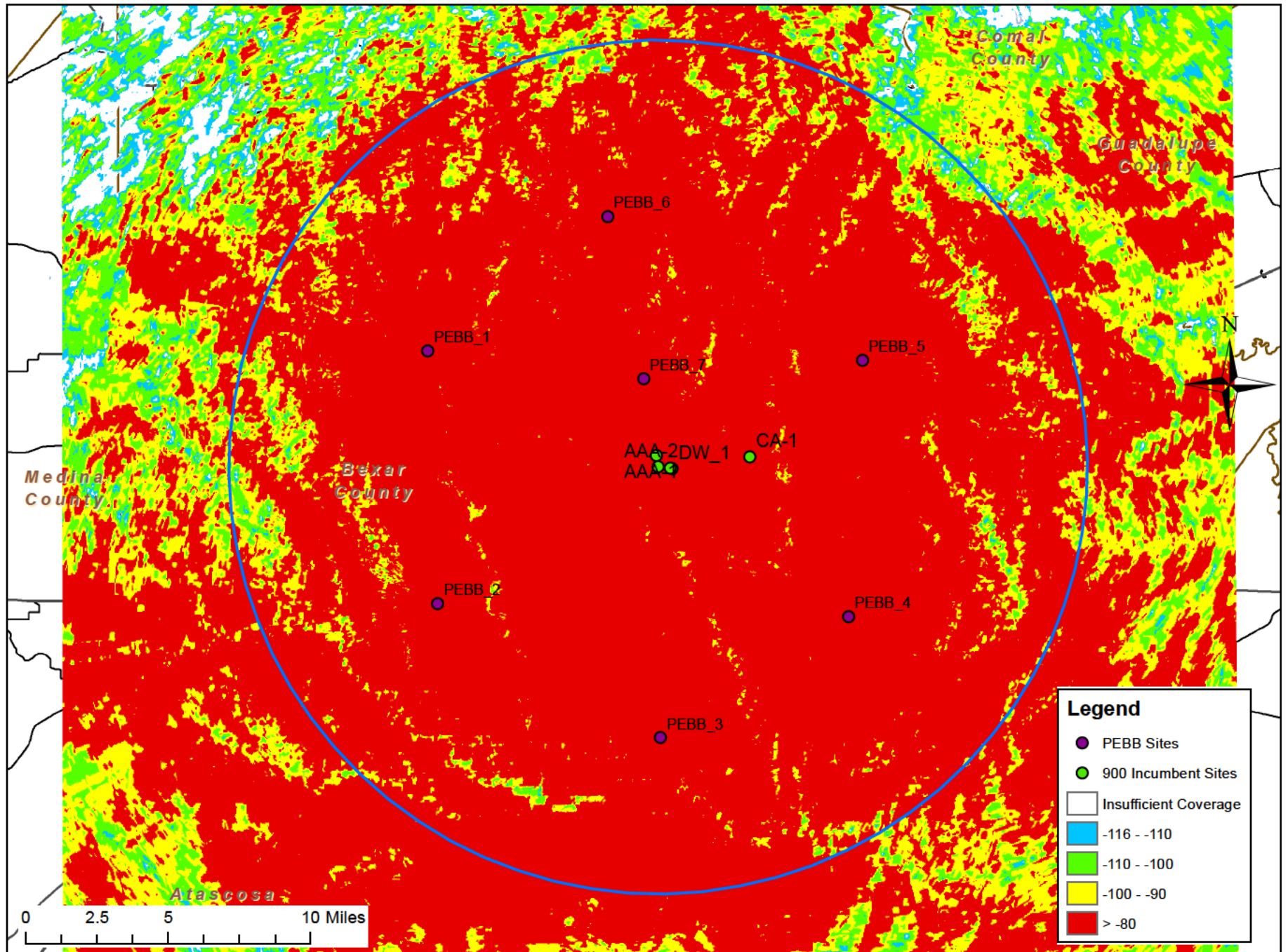
HAAT	Height Above Average Terrain
IF	Intermediate Frequency
IM	Intermodulation
ITU	International Telecommunications Union
LCRA	Lower Colorado River Authority
LMR	Land Mobile Radio
LNA	Low Noise Amplifier
LTE	Long Term Evolution (4G cellular standard)
MHz	Megahertz (10^6 cycles per second)
MIMO	Multiple Input, Multiple Output (an antenna diversity scheme)
MTA	Major Trading Area
NLCD	National Land Clutter Database
NOI	Notice of Inquiry
NPCS	Narrowband PCS (FCC Part 24, 901-902, 940-941 MHz)
NPSPAC	National Public Safety Planning Advisory Committee
ODU	Outdoor Unit
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access (LTE downlink)
OBE	Out-of-Band Emissions
P25	APCO Project 25 (interoperability standard)
PEBB	Private Enterprise Broadband
PFD	Power Flux Density (usually expressed in units of $\mu\text{W}/\text{m}^2$)
PIM	Passive Intermodulation
PLMR	Private Land Mobile Radio
PMI	Preventive Maintenance Inspection
PSD	Power Spectral Density (usually expressed as Watts/MHz)
PSEG	Public Service Electric and Gas
QPSK	Quadrature Phase Shift Keying
RB	Resource Block
RF	Radio Frequency
RSSI	Radio Signal Strength Indicator
SAR	Service Area Reliability
SC-FDMA	Single Channel Frequency Division Multiple Access (LTE uplink)
SDG&E	San Diego Gas & Electric
SMR	Specialized Mobile Radio
SNUG	Sensus FlexNet User Group
SSI	Strong Signal Interference
SSIM	Strong Signal Intermodulation
TDI	Time Delay Interference (in simulcast networks)
TDMA	Time Division Multiple Access
TGB	Total Gateway Base Station

TIA	Telecommunications Industries Association
TTA	Tower-Top Amplifier
UHF	Ultra High Frequency (300 MHz to 3 GHz)
ULS	FCC Universal Licensing System
UMTS	Universal Mobile Telecommunications Service (a 3G Service)
VHF	Very High Frequency (30 MHz to 300 MHz)

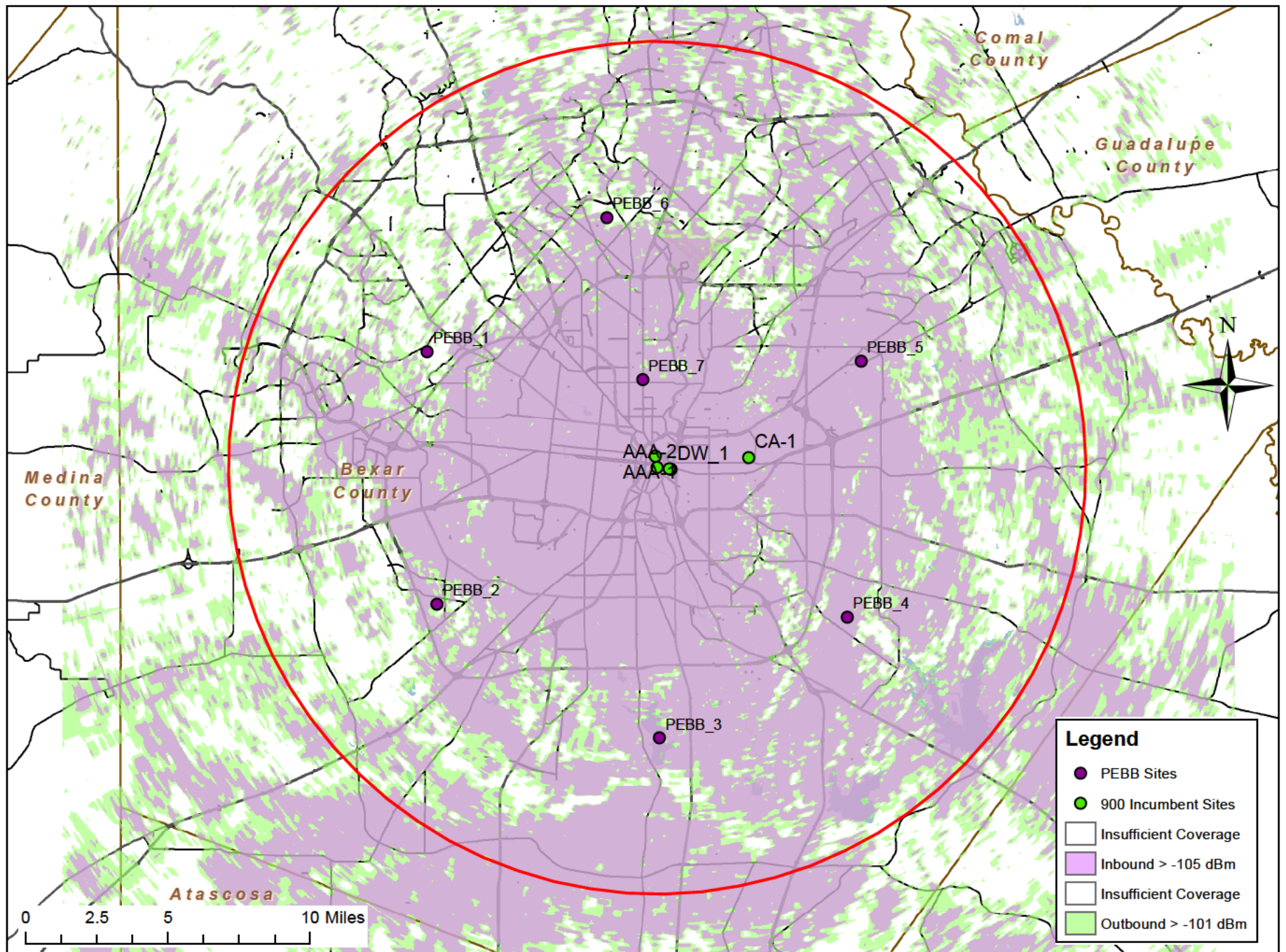
Appendix A - Coverage & Interference Plots
San Antonio, TX; Orlando, FL; San Diego, CA

Appendix A.1 - Coverage & Interference Plots for San Antonio, TX

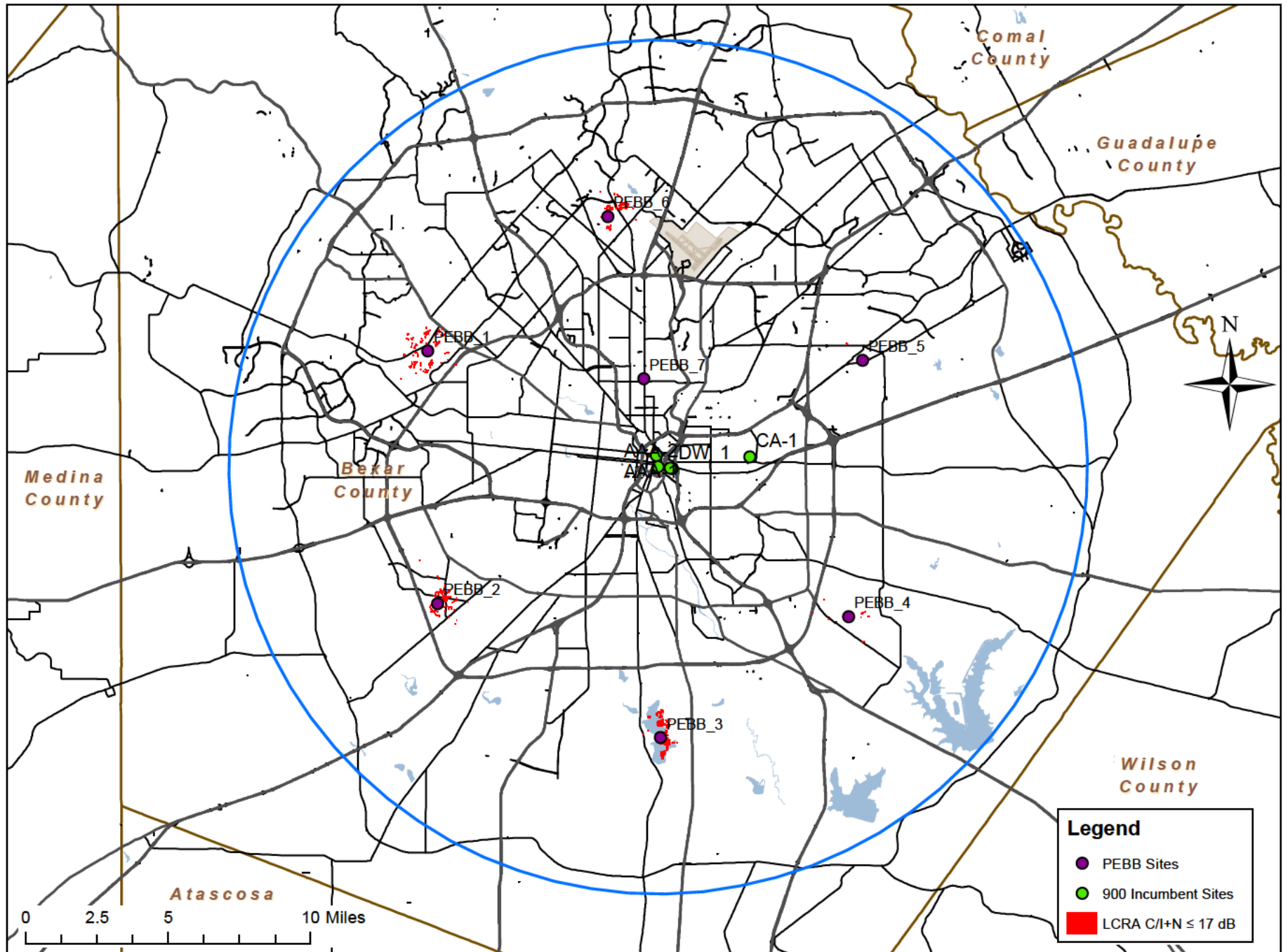
PEBB Coverage Heatmap



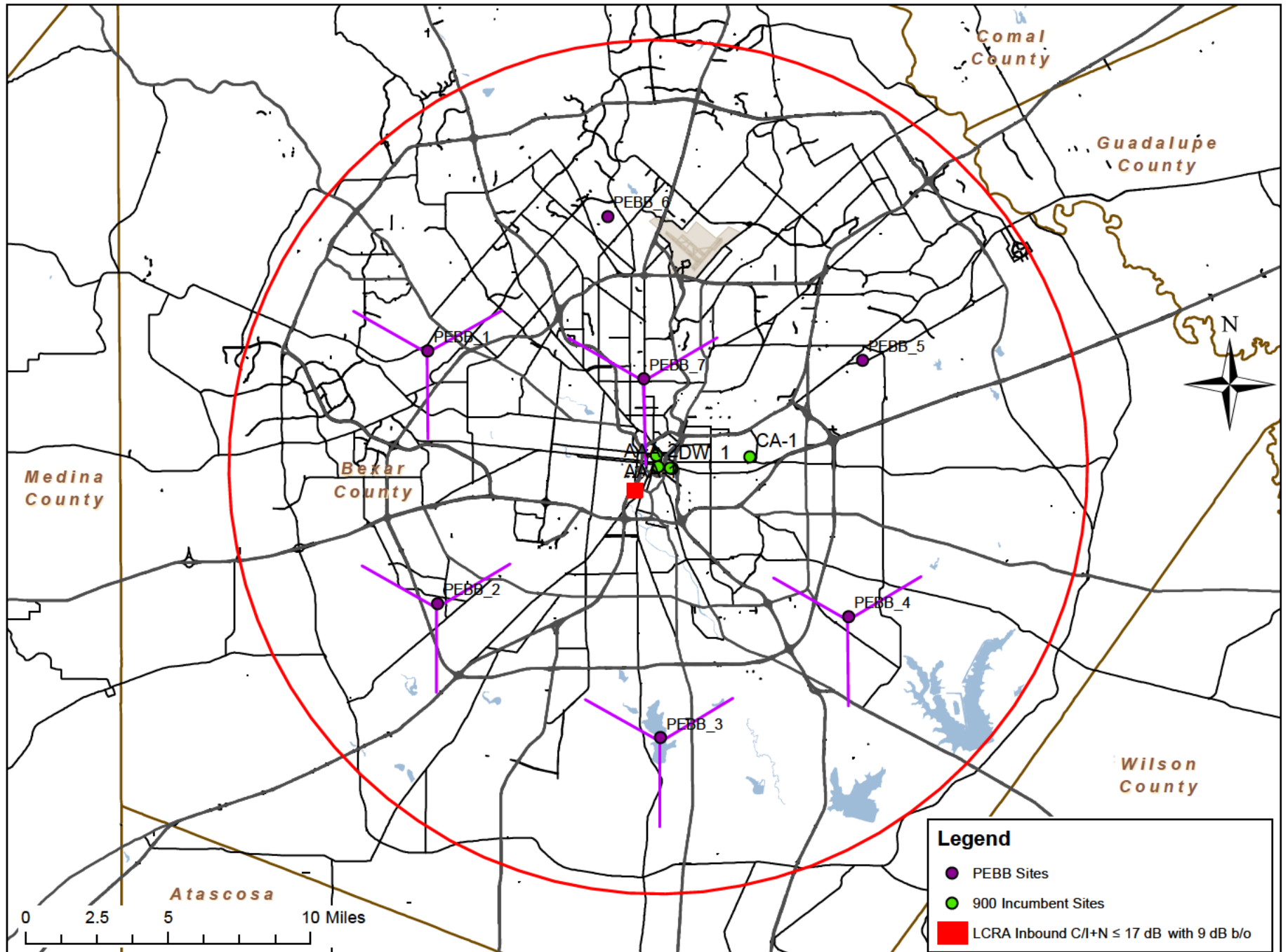
LCRA Coverage



LCRA Downlink Interference

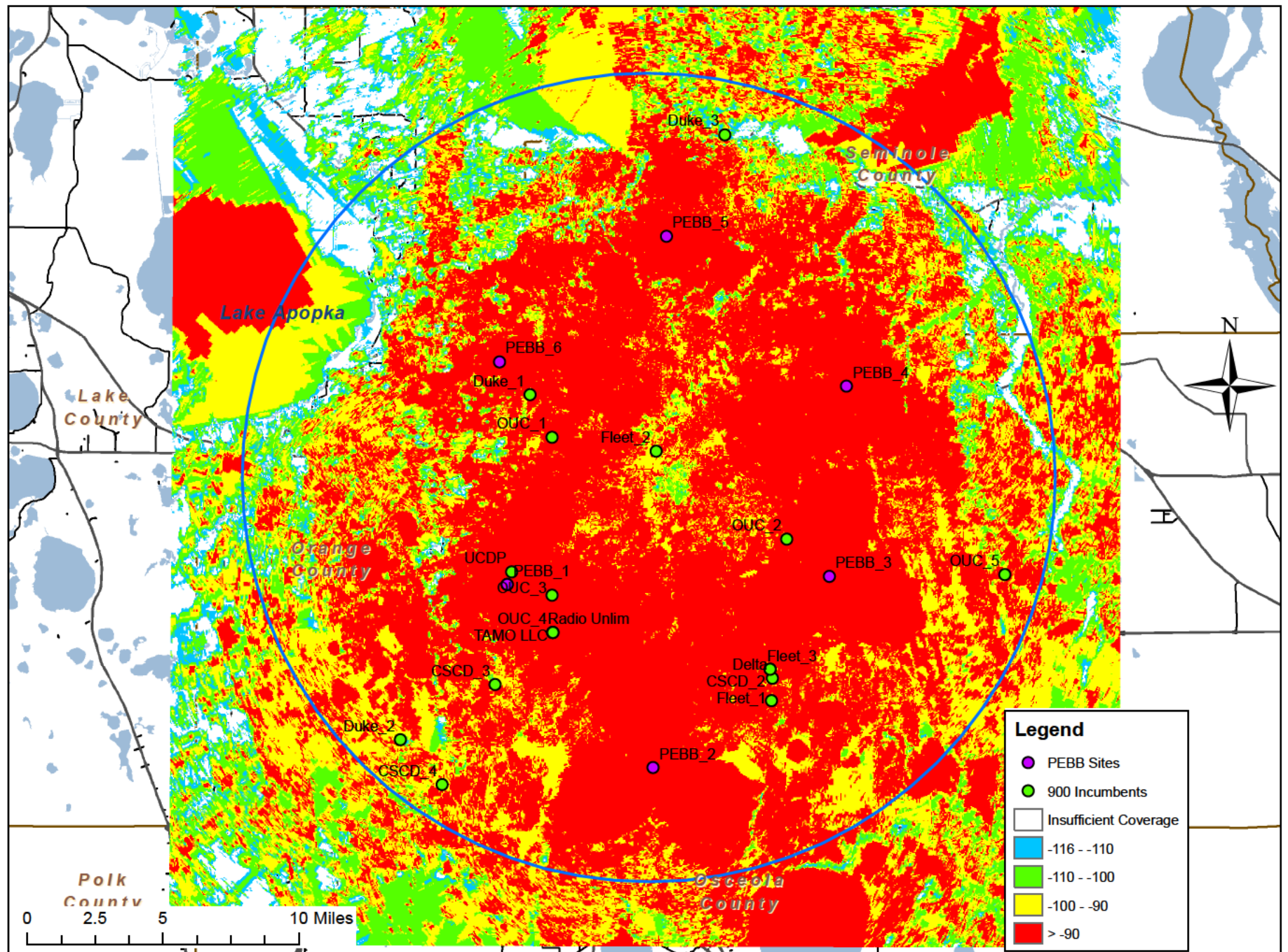


LCRA Uplink Interference (3 LTE Users)

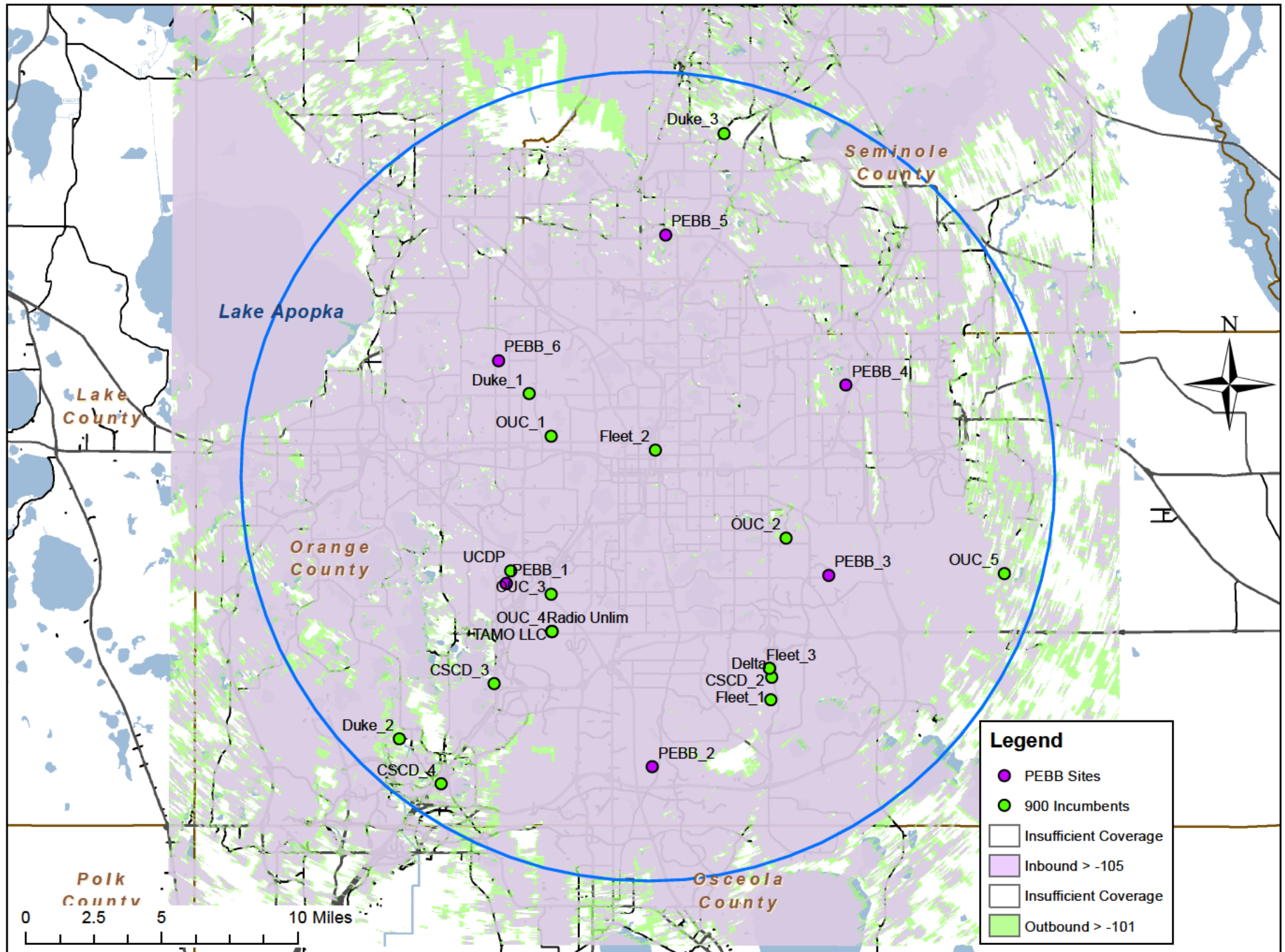


Appendix A.2 - Coverage & Interference Plots for Orlando, FL

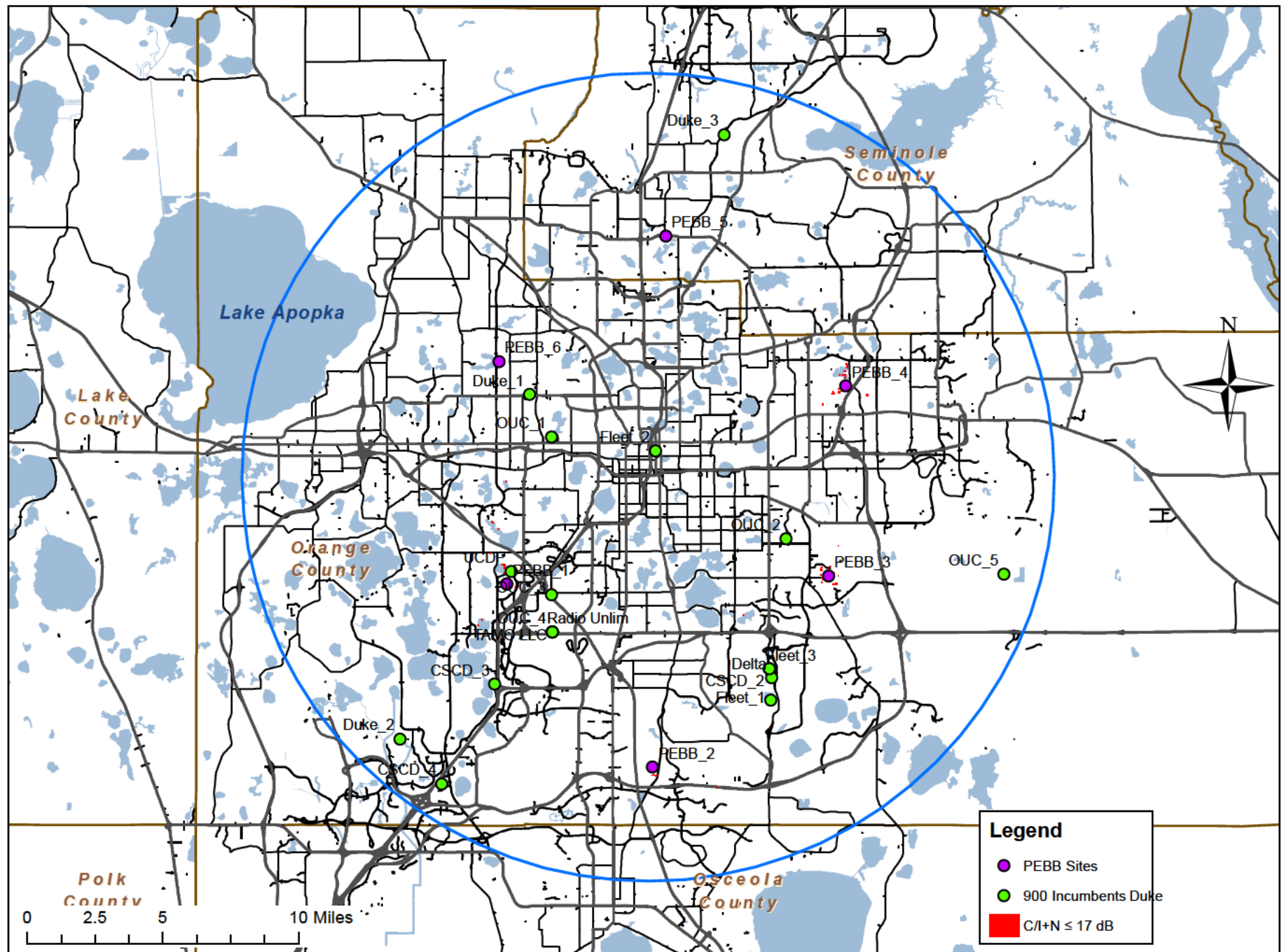
PEBB Coverage Heatmap



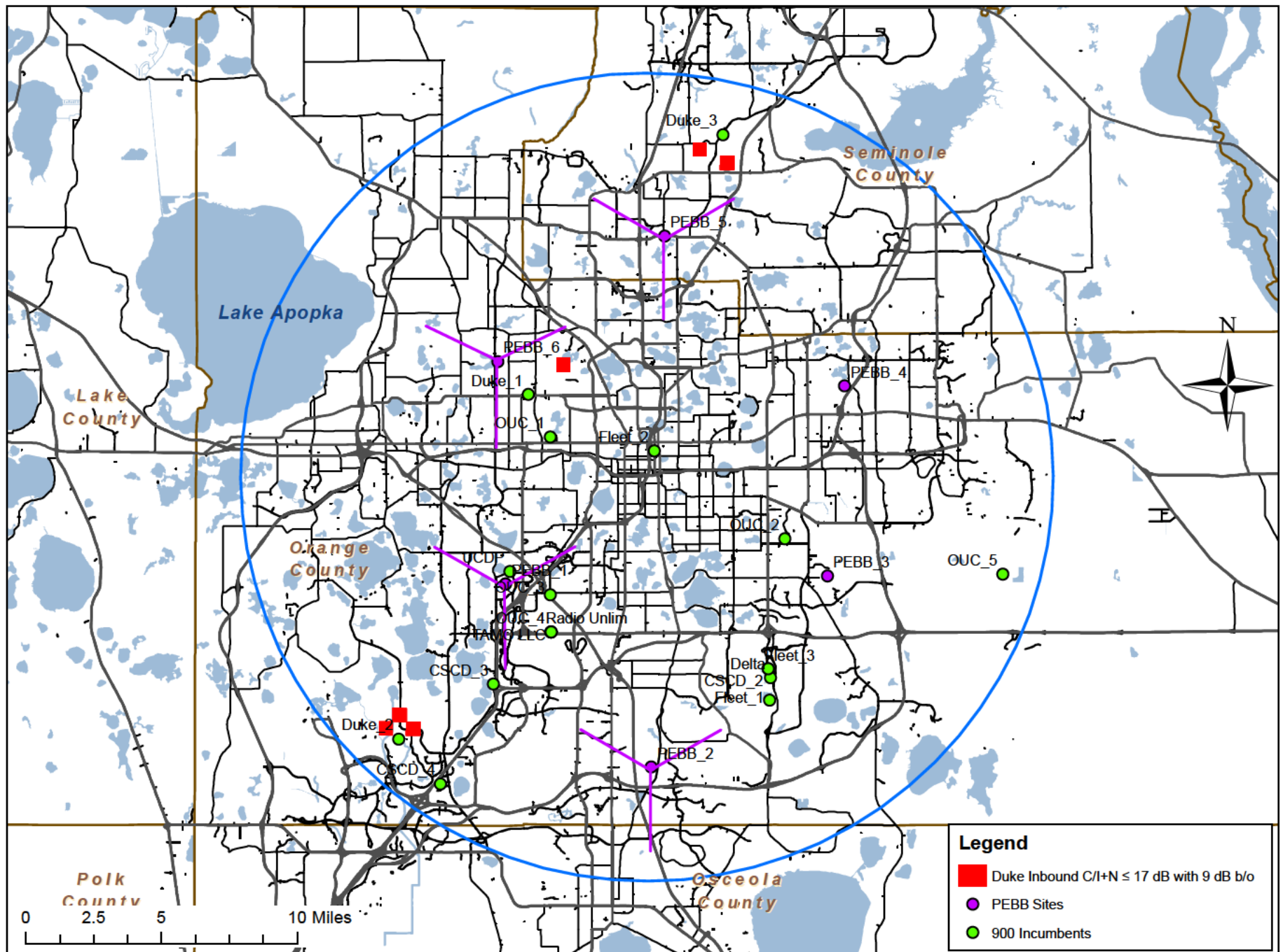
Duke Energy Coverage



Duke Energy Downlink Interference

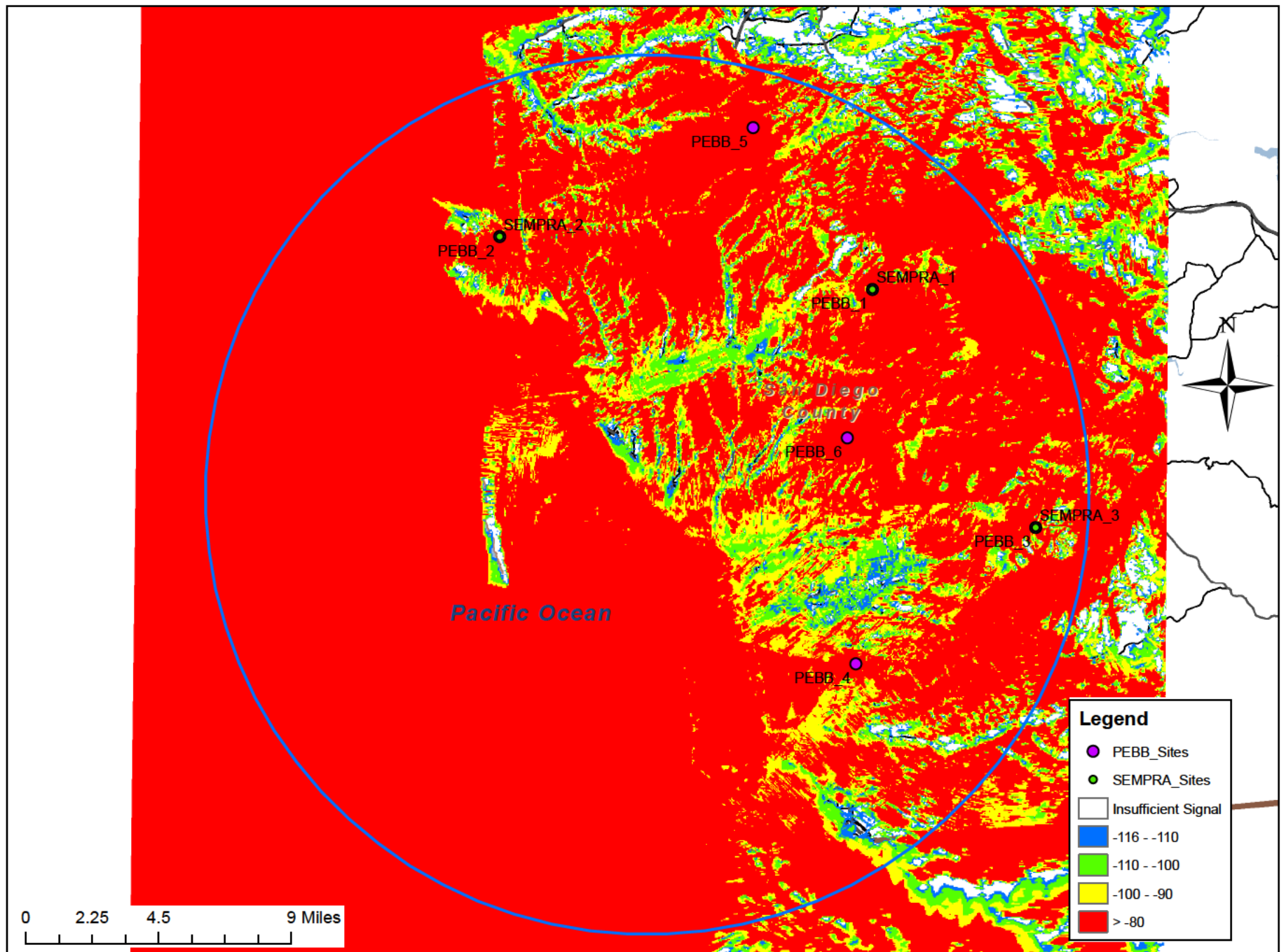


Duke Energy Uplink Interference(3 LTE Users)

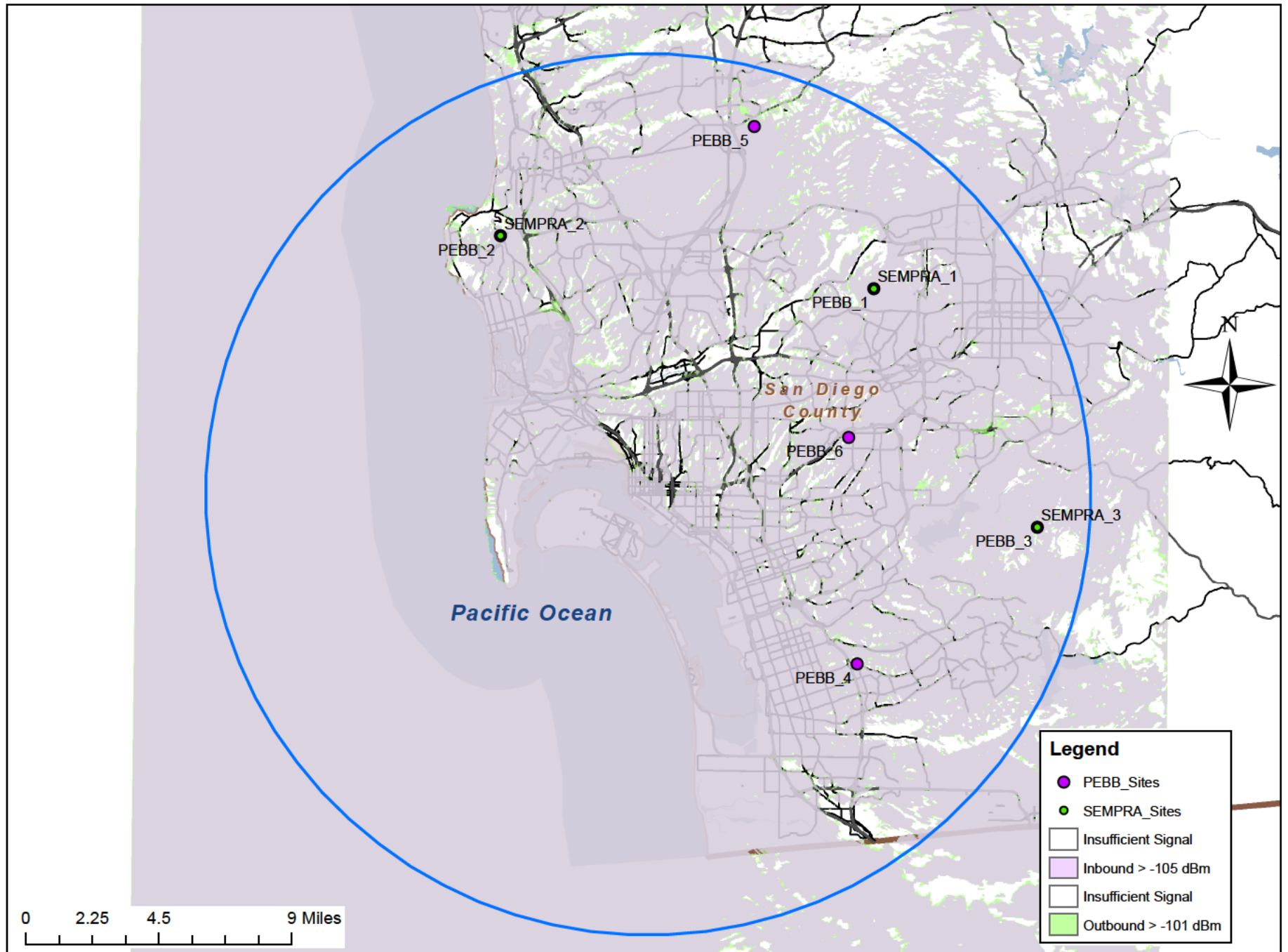


Appendix A.3 - Coverage & Interference Plots for San Diego, CA

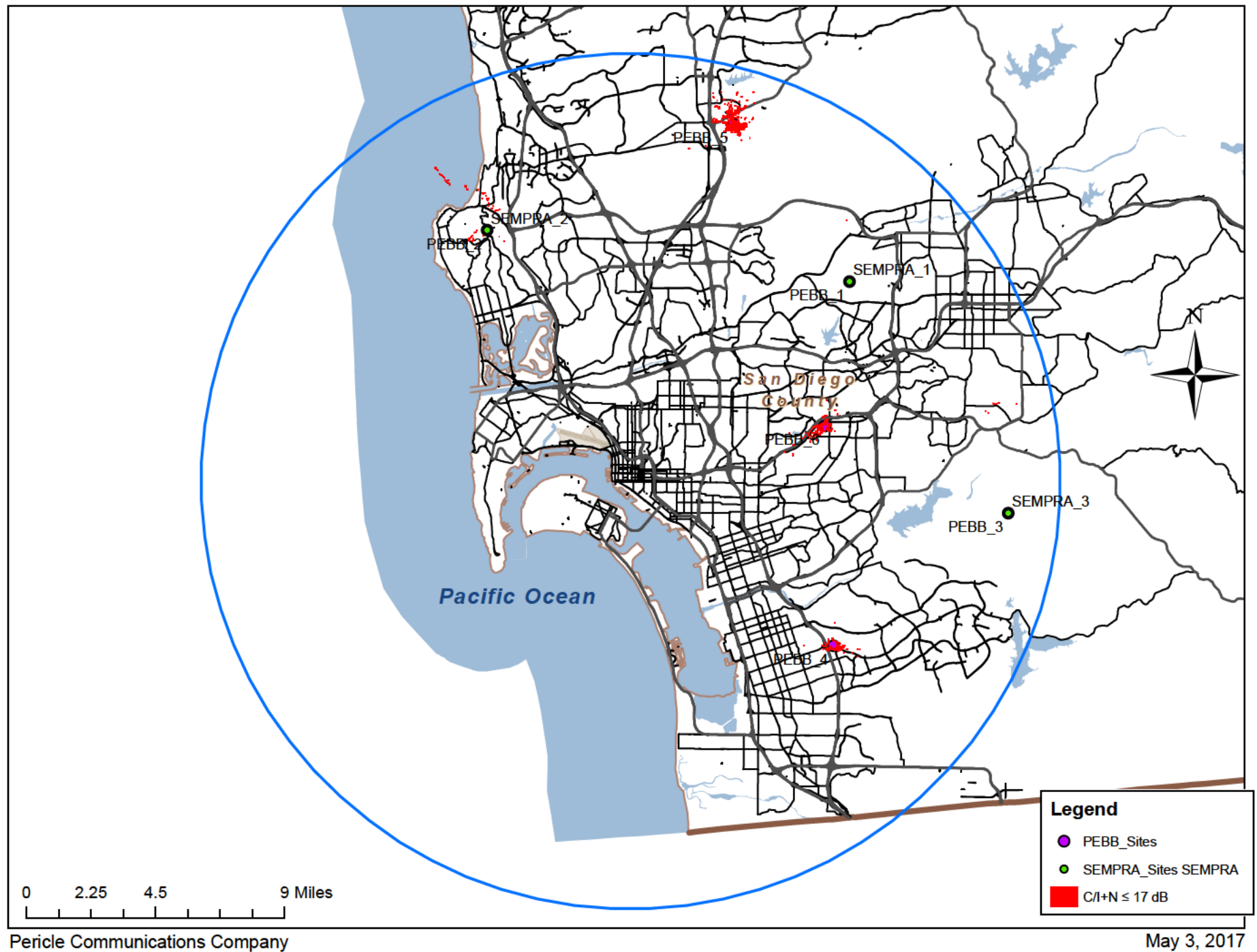
PEBB Heatmap



SEMPRA Coverage Map



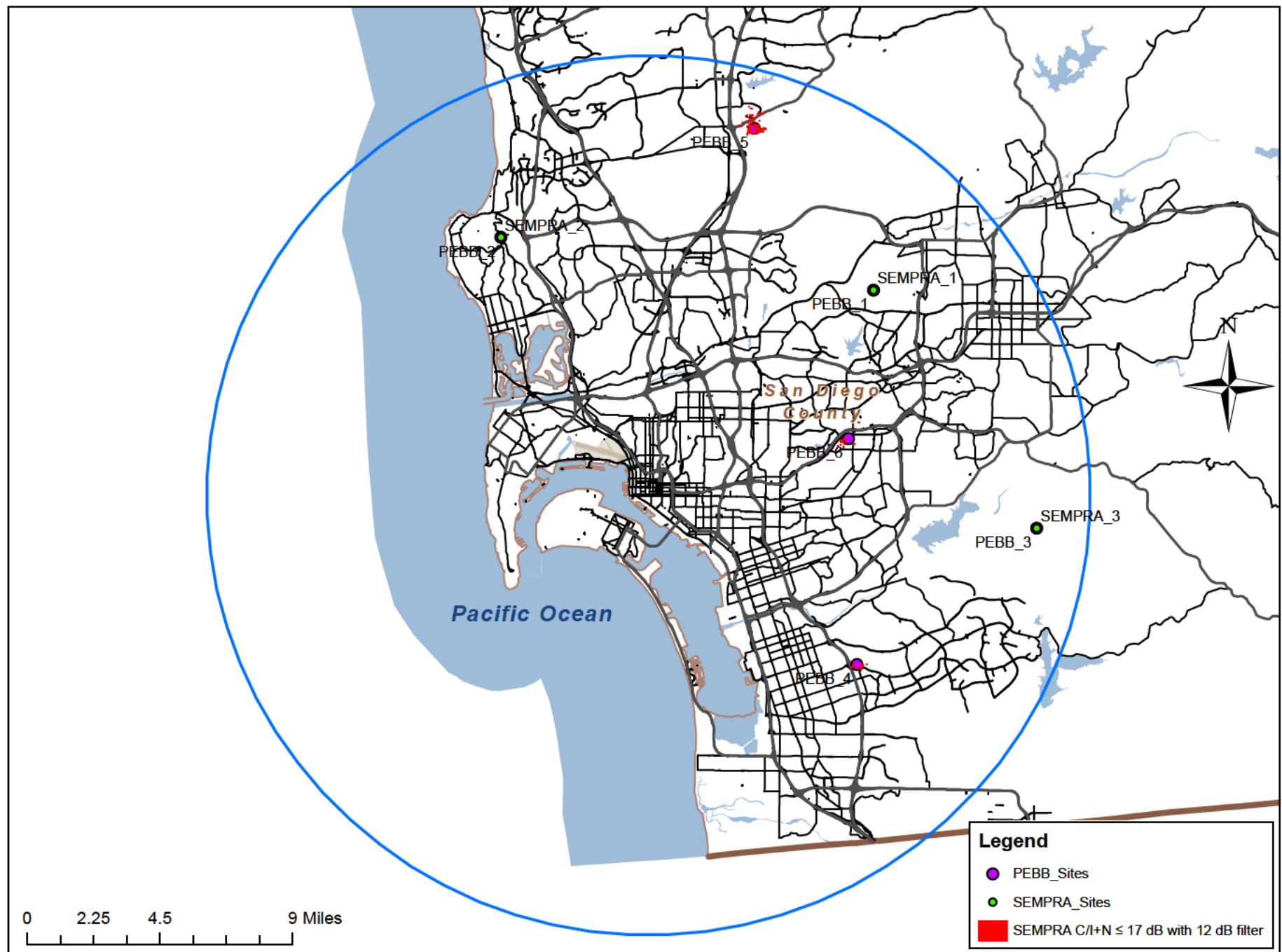
SEMPRA Downlink Interference



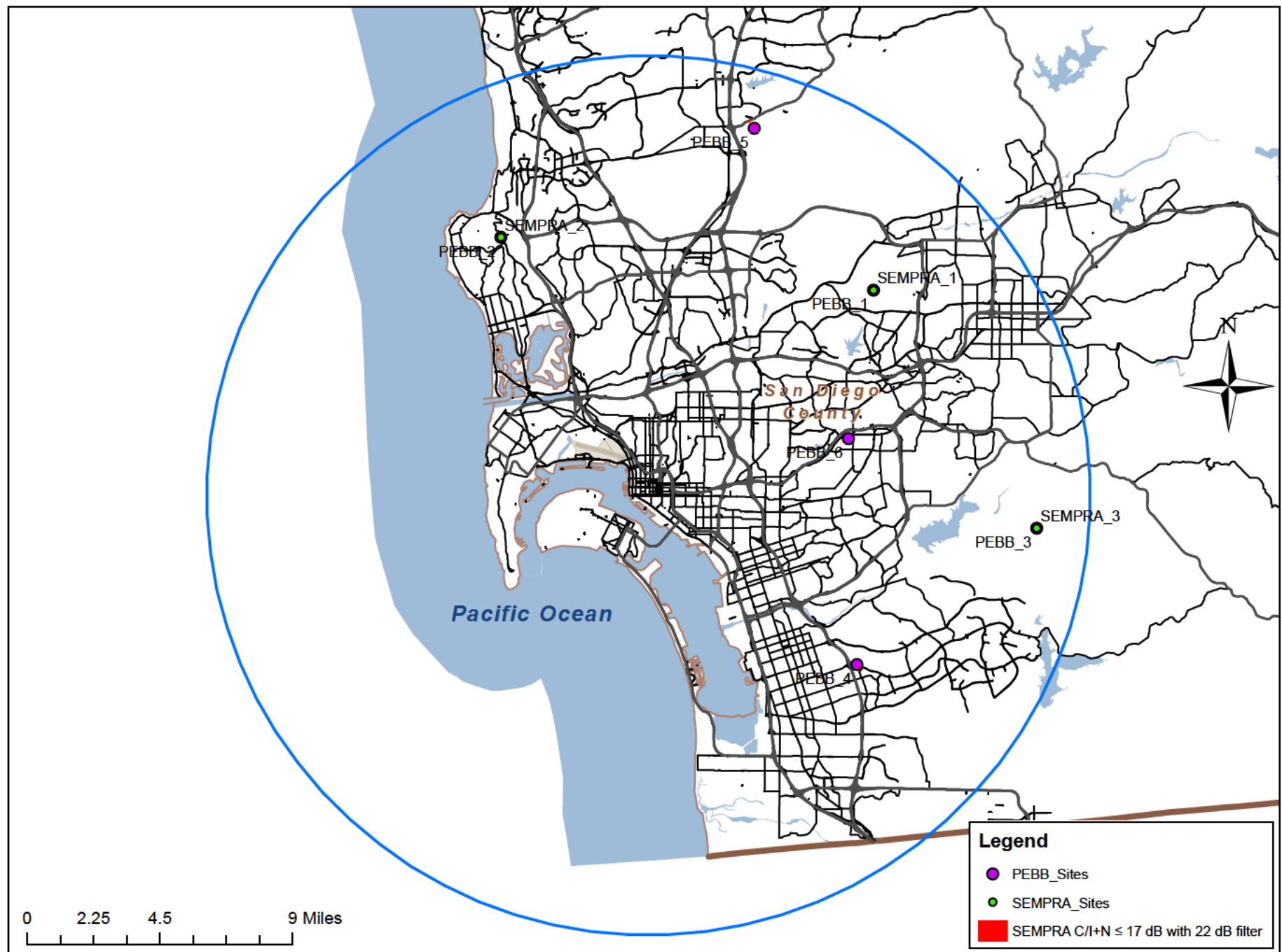
SEMPRA Uplink Interference (3 LTE Users)



SEMPRA Downlink Interference with 12 dB Filter



SEMPRA Downlink Interference with 22 dB Filter



Appendix B - 900 MHz Subscriber Radio Test Plan

September 29, 2017

1.0 Purpose

The primary purpose of these tests is to measure the effect of an adjacent 3 MHz LTE carrier on the receiver performance of a narrowband 900 MHz subscriber radio. The strong LTE carrier will result in spectral regrowth (a form of intermodulation) in the victim receiver. Other effects such as blocking may also occur. Because we are interested solely in the receiver performance, it is important to employ a signal generator with a pristine LTE signal (low transmitter spectral regrowth and phase noise) to eliminate OOB as a cause of receiver desense.

We will refer to the test as the Strong Signal Interference (SSI) rejection test. SSI rejection is defined as the difference in dB between the amplitude of the LTE carrier and the amplitude of the desired signal required to achieve 12 dB SINAD. The *desense* is derived from the interference rejection and is the difference in dB between this desired signal level and the 12 dB SINAD sensitivity of the receiver in the absence of interference. Three typical 900 MHz radios will be measured:

Motorola XPR-6580
Motorola XPR-7580
Motorola APX-4000

Three radios of each model number will be measured to preclude drawing general conclusions from outliers. In addition to the strong signal interference rejection, other industry standard tests will be conducted on each radio in accordance with TIA-603-D:

- 12 dB SINAD sensitivity
- Intermodulation rejection
- Blocking rejection

2.0 Subscriber Setup and Test Equipment Setup

The test equipment setup is shown in Figure 1. Two signals shall be generated and fed to the receiver antenna test port through a four port combiner. The combiner shall be selected for its linearity and port-to-port isolation and shall be tested for linearity. Unused ports shall be terminated. The first signal is the LTE carrier which emulates the interfering signal. The second signal is the narrowband subscriber desired signal.

The LTE carrier is generated by a Rhode & Schwarz model SMW200A Vector Signal Generator (VSG). The VSG shall be configured for optimized ACP (narrow) to reduce OOB. Nominal bandwidth shall be 3 MHz which results in 2.7 MHz occupied bandwidth (15 resource blocks, 12 subcarriers per resource block, 180 subcarriers). A cavity filter shall be used as necessary to reduce OOB to well below the level where receiver effects occur.

The desired signal will be generated by an HP 8920A service monitor. The desired signal shall be a 900 MHz carrier frequency modulated with a 1 kHz tone and 1.5 kHz deviation (60% of max). SINAD shall be measured using the 8920A audio analyzer with a 3 kHz low pass filter.

All coaxial cables, combiners and other test components shall be swept for insertion loss and recorded to adjust signal generator amplitudes to correct for insertion loss. Measurements shall be collected over six frequencies:

<u>Channel No.</u>	<u>RX Frequency</u>
1	935.0125 MHz
40	935.5000
80	936.0000
120	936.5000
148	936.8500
159	936.9875

3.0 Method of Test

3.1 Receiver Sensitivity. Test in accordance with TIA-603-D, paragraph 2.1.4.

3.2 Receiver Intermodulation Rejection. Test in accordance with TIA-603-D, paragraph 2.1.9 for 12.5 kHz channel spacing.

3.3 Blocking. Test in accordance with TIA-603-D, paragraph 2.1.21.

3.4 Strong Signal Interference Rejection. Follow the test plan described in Attachment A.

4.0 Presentation of Data

Record the measurement data in an Excel spreadsheet. Plot the SSI rejection as a function of interfering signal level from -40 to -10 dBm in 5 dB steps.

Attachment A - Strong Signal Interference Rejection Test Procedures

1.0 Introduction

The purpose of this test is to measure the ability of the 900 MHz subscriber radio receiver to reject receiver-induced strong signal interference which might be spectral regrowth, phase noise or blocking from a single LTE carrier. The receiver will be treated as a “black box” and the precise interference mechanisms occurring in the receiver are not important to the results. Because we are interested solely in the performance of the receiver as opposed to the transmitter, it is important that a pristine LTE carrier be used with OOB well below the level where receiver effects occur.

2.0 Definitions

2.1 The standard input signal is a frequency modulated carrier using a 1 kHz tone and 60% of maximum deviation (e.g., 1.5 kHz deviation for 2.5 kHz max deviation on a 12.5 kHz channel).

2.2 The reference sensitivity, P_{REF}, is the received signal amplitude in dBm required to achieve 12 dB SINAD.

2.3 SSI Rejection. Strong signal interference rejection is defined the ability of a receiver to prevent an undesired input signal from causing degradation to the reception of a desired signal. In this case, a single LTE carrier is used to emulate an interfering signal. It is expressed as the ratio (in dB) of the level of the interfering LTE signal to the minimum amplitude of the desired signal required to achieve 12 dB SINAD.

3.0 Characteristics of Test Equipment

The receiver under test is the portable or mobile radio subscriber. This radio should be inspected to ensure it is in proper working order before testing starts. Interfering signals are normally generated by two signal generators but in this case only a single VSG will be used. If phase noise or other OOB limits the test, a cavity filter should be used at the output of the VSG. A network analyzer or cable/antenna tester is required to accurately measure the insertion loss of all couplers, power combiners and attenuators (if used) in the test circuit. Double-shielded or solid shield coaxial cable is required to minimize unwanted coupling. All test equipment shall have current calibration traceable to NIST.

4.0 Methods of Measurement

4.1 Setup. Configure the test equipment as shown in Figure 1. Connect the HP 8920A (desired signal) and SMW200A (LTE interfering signal) through a four port combiner with the output

connected to the subscriber radio antenna port (or test antenna port). Connect the audio output of the subscriber radio to the audio input of the 8920A (SINAD meter). Configure the SMW200A to generate a nominal 3 MHz wide LTE signal centered on 938.5 MHz, E-TM1.1 Base Station Conformance Waveform and optimized for ACP (narrow). Measure and record the out-of-band emissions in a 8.5 kHz equivalent noise bandwidth (IF bandwidth of subscriber) at each test frequency. Be aware that the spectrum analyzer phase noise and sensitivity may prevent accurate measurement of weak OOB. If necessary, connect a cavity filter tuned to pass 937.15-939.85 MHz with at least 12 dB rejection at 937 MHz between the SMW200A and the power combiner. Use the Network Analyzer to measure insertion loss of test components and calibrate for cable, cavity filter (if used) and combiner loss.

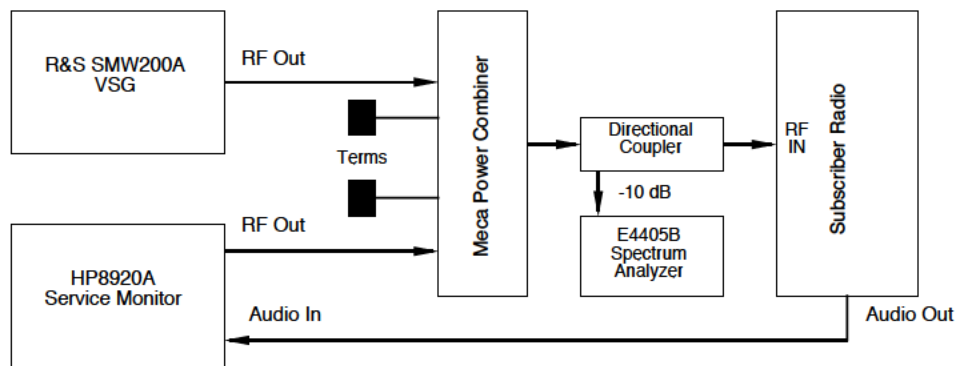


Figure 1 - Test Equipment Setup

Verify that the subscriber radios under test are configured (via codeplug) properly for this test, including setting the RF AGC feature to “STD” (XPR-6580 and APX-4000 only). The radio should be configured for conventional duplex operation, analog FM, maximum deviation of 2.5 kHz, no audio squelch, carrier squelch set below the best case sensitivity.

4.2 Strong Signal Interference Rejection.

4.2.1 Set the LTE signal amplitude to -40 dBm as measured at the antenna port. This is the level of the interfering signal.

4.2.2 Configure the HP 8920A to generate a desired signal on test frequency #1. This signal shall be frequency modulated with a 1 kHz tone and 1.5 kHz deviation.

4.2.3 Increase the desired signal amplitude on the HP 8920A until the SINAD is 12 dB. The strong signal IM rejection is the difference (in dB) between the interfering level and the desired signal level. Note that, depending on the rejection ability of the receiver and the sensitivity of the receiver, the desired signal level may be equal to the receiver sensitivity.

4.2.4 Repeat the above steps for LTE interferer amplitudes of -35, -30, -25, -20, -15, and -10 dBm.

4.2.5 For each subscriber radio, plot SSI rejection versus interferer amplitude from -40 to -10 dBm in 5 dB steps.

4.2.6 Repeat above for all test frequencies (six total).

4.3 Strong Signal IM (SSIM) Rejection (emulation of 800 MHz Scenario at 900 MHz).

4.3.1 Set the 1.25 MHz CDMA and 5 MHz LTE signal amplitude each to -40 dBm as measured at the antenna port. This is the level of the interfering signals. Configure the CDMA waveform to the cdma2000 downlink. (The SMW200A can transmit the two waveforms simultaneously.) Set the CDMA center frequency to 937.8375 MHz and the LTE center frequency to 941.2375 MHz. See Figure 2.

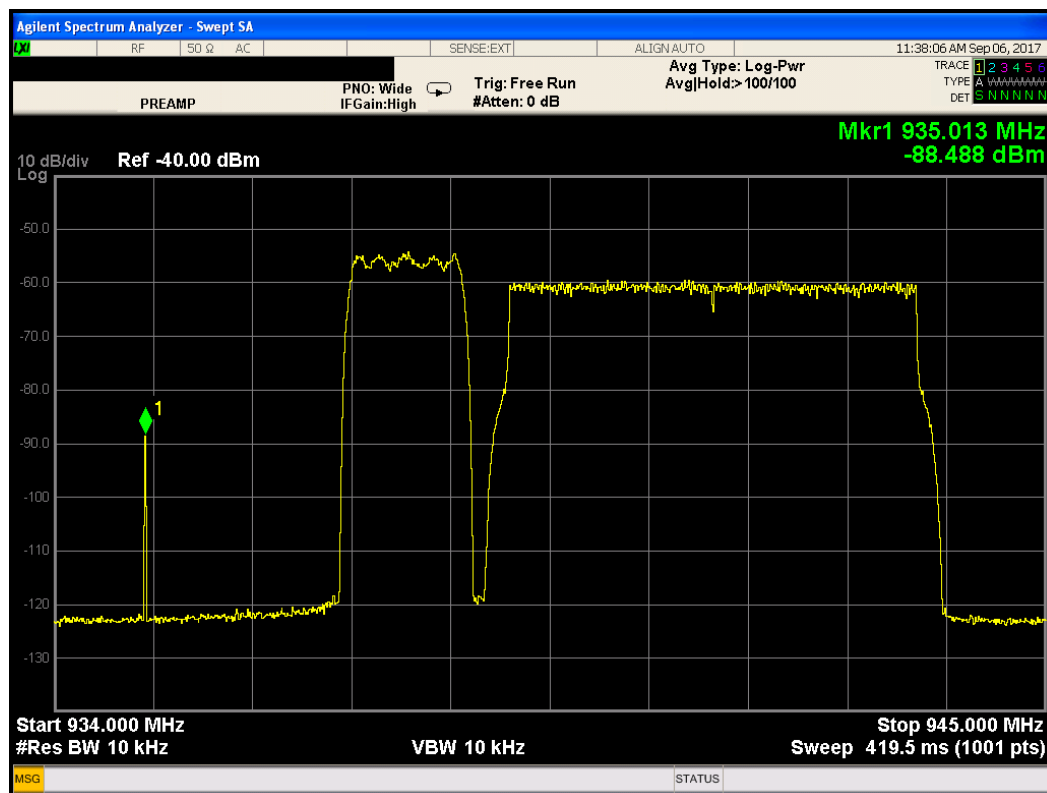


Figure 2 - Spectrum Analyzer Trace of 800 MHz Scenario at 900 MHz

4.3.2 Configure the HP 8920A to generate a desired signal on 935.0125 MHz. This signal shall be frequency modulated with a 1 kHz tone and 1.5 kHz deviation.

4.3.3 Increase the desired signal amplitude on the HP 8920A until the SINAD is 12 dB. The strong signal IM rejection is the difference (in dB) between the interfering level and the desired signal level. Note that, depending on the rejection ability of the receiver and the sensitivity of the receiver, the desired signal level may be equal to the receiver sensitivity.

4.3.4 Repeat the above steps for CDMA and LTE interferer amplitudes of -35, -30, -25, -20, -15, and -10 dBm.

4.3.5 For each subscriber radio, plot SSIM rejection versus interferer amplitude from -40 to -10 dBm in 5 dB steps.

4.4 Test Equipment Required.

- Rhode & Schwarz SMW200A VSG, S/N 101086, Option B22 (low phase noise)
- Agilent E4433B VSG, S/N US40051614
- HP 8920A Service Monitor, S/N 3550A07553
- Agilent 5071B Network Analyzer, S/N MY42403489
- Agilent E4405B Spectrum Analyzer, S/N US40520780
- MECA four port combiner, Model #804-4-1.500V
- Narda 10 dB Directional Coupler, Model 3001.1, S/N 32123
- Tensolite test coaxial cables

Record S/N and calibration data for each instrument.

- END OF TEST PLAN -

Appendix C - Manufacturer Data Sheets

Bittium

Bittium Tough Mobile Secure and Strong LTE Smartphone



The **Bittium Tough Mobile** smartphone is designed and built for Security, Public Safety, and other professional markets. The sleek and rugged Bittium Tough Mobile provides superior security and compliance with carrier-grade feature requirements. These include hardware based security, a powerful quad-core LTE-Advanced processor, Android 5.1, a configurable button for PTT, military grade mechanics, and support for LTE Band 14. Bittium can also provide product customization, solution integration, and other services to address unique customer requirements.

FOR MORE INFORMATION, PLEASE CONTACT:

sales@bittium.com



Secure

World's most secure mobile platform with hardened OS. Options for customer-specific security features.



Powerful

2.3GHz quad-core processor provides performance for the most demanding applications with low power consumption.



Global

9 LTE frequencies in a single device configuration provides global 4G connectivity.



Robust

Industrial design and mechanical packaging to meet high environmental and durability demands. IP67 water and dust resistance, MIL-STD-810G shock resistance.



Proven

Base platform rigorously tested and validated by leading commercial wireless carriers ensuring interoperability and feature compatibility across various network configurations.

Bittium Tough Mobile

Specifications



Qualcomm Snapdragon 801

- Quad-core Krait CPU 2.3GHz
- Adreno 330 3D graphics accelerator
- Hexagon QDSP 600 MHz

Operating System

- Operating system: Android™ 5.1 Lollipop
- Available with or without Google Mobile Services

Memory

- 2GB LPDDR3 RAM
- 16GB eMMC Mass Storage
- Micro SD expansion slot

Security

- Secure boot with HW-enabled integrity
- Runtime integrity
- Application permission firewall
- Secure data storage for user credentials and encryption keys
- Encrypted mass memory
- Tampering detection
- PGP encrypted email
- FIPS 140-2 compliant HW cryptography
- Secure Suite (optional)
 - Mobile VPN
 - Device management
 - Remote attestation
 - Enterprise app library
 - Log server
 - Secure push service



Battery

- 2420mAh Li-Ion

Wireless Connectivity

LTE

- 3GPP rel10 (LTE Advanced)
- FDD Cat4, DL 150 Mbit/s, UL 50 Mbit/s
- IMS, VoLTE-ready
- Band configuration:
 - US: B2 (1900), B4 (1700), B5 (850), B17 (700), B13 (700), B14 (700)
 - EU: B3 (1800), B7 (2600), B20 (800)
- Carrier Aggregation: supported

UMTS/HSPA

- 3GPP rel8, HSPA+, DL 42 Mbit/s, UL 5.76 Mbit/s
- Band configuration:
 - US: B2 (1900), B4 (1700), B5 (850)
 - EU/APAC: B1 (2100), B8 (900)

GSM/GPRS/EDGE

- 850/900/1800/1900 MHz

Other Radios

- Wi-Fi 802.11 a/b/g/n/ac
- BT 4.0
- NFC

Push-to-talk (PTT)

- Configurable button for PTT, camera, etc.

Sensors

- 3D Gyroscope
- 3D Accelerometer
- 3D Magnetometer
- Proximity Sensor
- Ambient Light Sensor
- Barometer

Imaging and Video

- 8 MP with Autofocus and LED Flash
- 2 MP for front facing applications
- Full HD video capture and playback

Audio

- High-performance speakers
- Multi-microphone active noise cancelling
- Earpiece and microphone
- 3.5mm headset connector

Positioning

- aGPS/Glonass
- iZat™ positioning framework

Mechanical

- Size 141mm x 75,5mm x 13,5mm
- Weight 180g
- IP67 water and dust resistant
- MIL-STD-810G shock resistant

Operating range

- -20 C...+60 C

Certifications

- FCC, CE
- Finnish national approval for RESTRICTED classification level (with Secure Suite)

Display

- 5" Full HD (1080*1920) LCD
- Glove-usable capacitive touch, functional also in wet conditions.

Interfaces

- USB3.0 with fast charging
- Wireless display (Miracast compliant)
- Dual-SIM slots



Bandpass Filter for Pacific Datavision

Tel: 201-342-3338

Fax: 201-342-3339

www.cciprotects.com

General Information



Communication Components, Inc. Bandpass filter allows a 2.8 MHz band in the 937-940 MHz Band pass, while rejecting signals within 100 KHz of the passband.

The CCI Bandpass filter provides performance for the passband with low insertion loss, low Intermodulation, and high power handling. Excellent return loss delivers the best match to the antennas and base station, saving precious

transmit power. The Bandpass filter is the ideal solution for encompassing a 3MHz LTE carrier and rejecting all spectrum regrowth



Model
BP-937-940-I

Contents:

General Info and Technical Description	1
Electrical and Mechanical Specifications	2
Block Diagrams & Mechanical Drawings	3

Features:

- Low Loss
- Good Rejection
- Good IM
- High reliability

Technical Description

The bandpass filter consists of multiple cavity resonators utilizing high dielectric ceramics to achieve 25dB rejection within 100 KHz of the pass band. Extensive temperature compensation is employed to insure frequency stability over the specified temperature range.

Bandpass Filter Electrical & Mechanical Specifications



Description	Typical Specifications
Electrical Specifications	
Passband	2.8 MHz Wide (centered within 937-940 MHz)
Insertion loss (1.6 MHz Bandwidth)	1.0 dB maximum
Insertion loss (2.6 MHz Bandwidth)	1.5 dB maximum
Return Loss	20 dB Minimum
Rejection (within 100 KHz of Passband)	25 dB minimum
Power Handling	200 Watts Average, 3KW peak
IM3	-155 dBc min., 2 x 20 W carriers
Common Specifications	
Impedance	50 Ohms
Mechanical Specifications	
Connectors	7-16 DIN-Female (Long Neck) x 2
Dimensions (Bracket & Connectors not included)	18" x 7" x 4" (457.2 x 177.8 x 101.6 mm) - Single Unit
Weight	Approximately 40 LBS
Finish	Epoxy Powder Coat
MTBF	500,000 Hours Minimum
Mounting	19" Rack Mount
Environmental Specifications	
Operating Temperature	25°F +/-10°
Environmental Protection	Indoor Rated
Relative Humidity	0– 50%

All specifications are subject to change. The latest specifications are available at www.ccipproducts.com

Communication Components Inc.

Tel: 201-342-3338

Fax: 201-342-3339

3/16/2015

Page 2

Revision 0.5



89 Leuning Street
South Hackensack, NJ 07606
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WWW.CCIPRODUCTS.COM



Ordering Information:

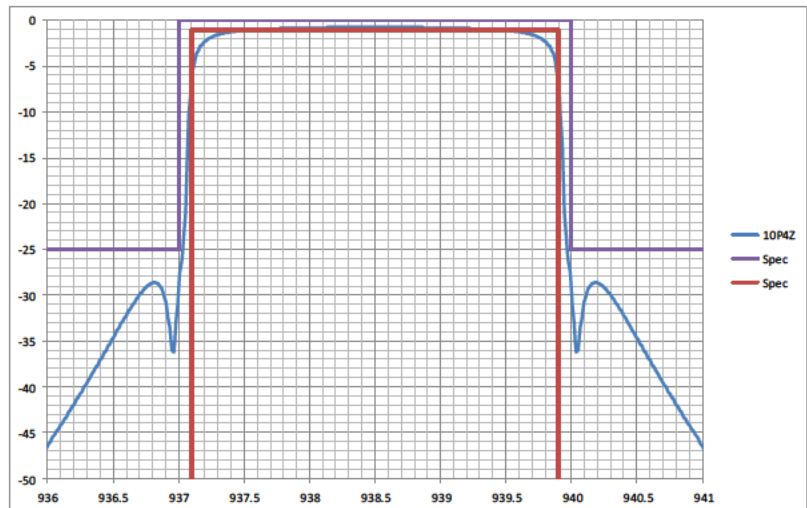
- ◆ **Model BP-937-940-I**
(Single Unit)

Options:

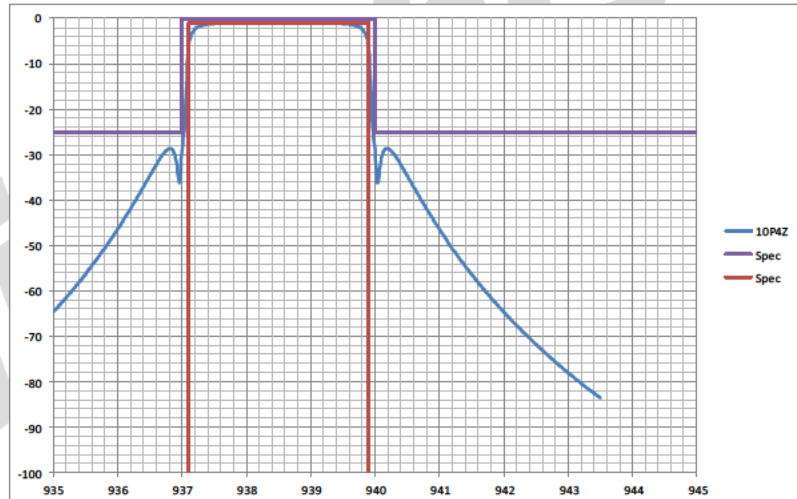
- ◆ **19" Mounting Tray**

Accessories:

Bandpass Filter Narrowband and Wideband Response Characteristics



Narrowband Characteristics



Wideband Characteristics

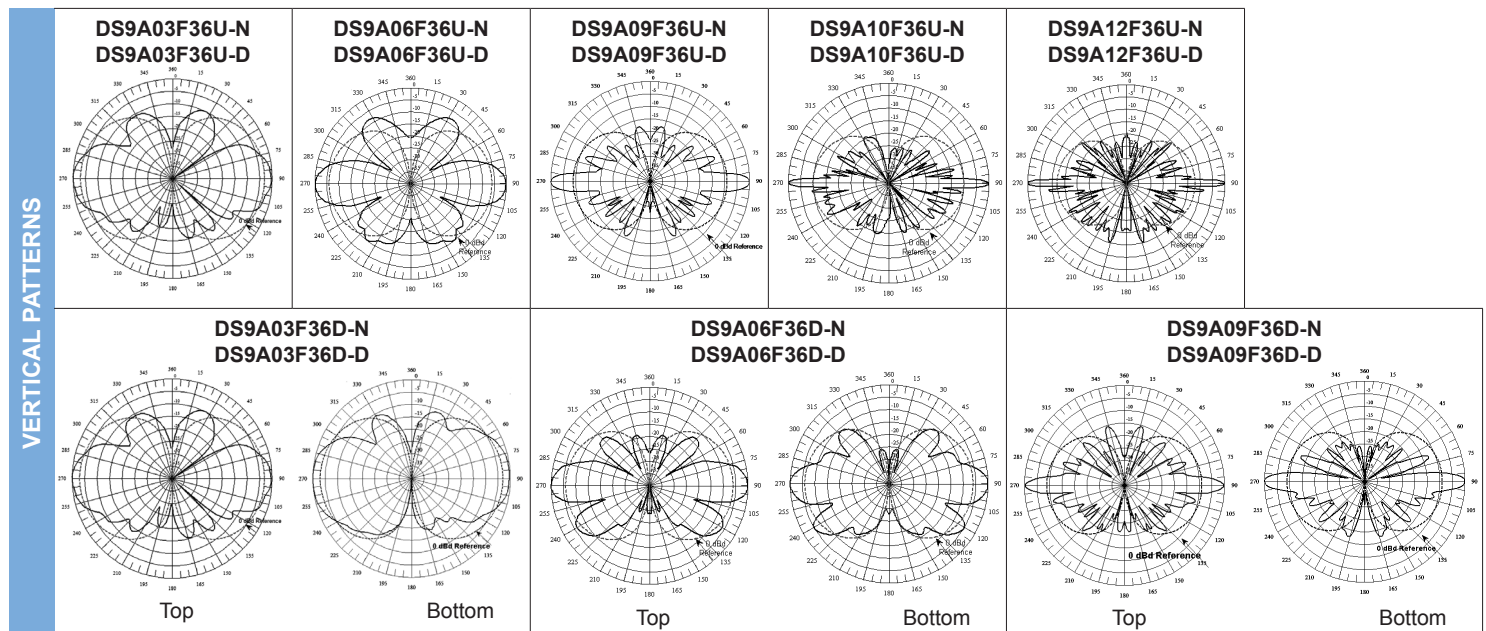
Bandpass Unit Outline Drawing

Dimensions in
inches (mm)

Communication Components Inc.

900 MHz Omni Antennas (890-960 MHz)

		890-960 MHz															
Model Number		DS9A03F36U-N	DS9A03F36U-D	DS9A06F36U-N	DS9A06F36U-D	DS9A09F36U-N	DS9A09F36U-D	DS9A10F36U-N	DS9A10F36U-D	DS9A12F36U-N	DS9A12F36U-D	DS9A03F36D-N	DS9A03F36D-D	DS9A06F36D-N	DS9A06F36D-D	DS9A09F36D-N	DS9A09F36D-D
Input Connector		N(F)	7/16 DIN	N(F)	7/16 DIN	N(F)	7/16 DIN	N(F)	7/16 DIN	N(F)	7/16 DIN	N(F)	7/16 DIN	N(F)	7/16 DIN	N(F)	7/16 DIN
Type		Single		Single		Single		Single		Single		Dual		Dual		Dual	
ELECTRICAL	Bandwidth, MHz	70		70		70		70		70		70		70		70	
	Power, Watts	500		500		500		500		500		350		350		350	
	Gain, dBd	3		6		9		10		12		3		6		9	
	Horizontal Beamwidth, degrees	360		360		360		360		360		360		360		360	
	Vertical Beamwidth, degrees	30		16		8		6		3		30		16		8	
	Beam Tilt, degrees	0		0		0		0		0		0		0		0	
	Isolation (minimum), dB	N/A		N/A		N/A		N/A		N/A		40		40		45	
MECHANICAL	Number of Connectors	1		1		1		1		1		2		2		2	
	Flat Plate Area, ft ² (m ²)	0.24 (0.02)		1.28 (0.12)		2.26 (0.21)		3.25 (0.3)		4.33 (0.4)		1.38 (0.13)		2.27 (0.21)		3.83 (0.36)	
	Lateral Windload Thrust, lbf(N)	11 (48)		48 (214)		85 (377)		122 (543)		163 (723)		31 (139)		85 (374)		144 (641)	
	Survival Wind Speed without ice, mph(kph)	437 (703)		250 (402)		150 (241)		105 (169)		75 (121)		379 (610)		150 (241)		90 (145)	
	with 0.5" radial ice, mph(kph)	319 (513)		225 (362)		127 (204)		88 (142)		60 (97)		294 (473)		125 (201)		75 (121)	
	Mounting Hardware included	DSH2V3R		DSH2V3R		DSH3V3R		DSH3V3N		DSH3V3N		DSH2V3R		DSH3V3R		DSH3V3N	
DIMENSIONS	Length, ft(m)	2.9 (0.9)		6.7 (2)		11.4 (3.5)		16.3 (5)		21.8 (6.6)		8 (2.4)		11.4 (3.5)		19.2 (5.9)	
	Radome O.D., in(cm)	2 (5.1)		3 (7.6)		3 (7.6)		3 (7.6)		3 (7.6)		3 (7.6)		3 (7.6)		3 (7.6)	
	Mast O.D., in(cm)	2.5 (6.4)		2.5 (6.4)		2.5 (6.4)		2.5 (6.4)		2.5 (6.4)		2.5 (6.4)		2.5 (6.4)		2.5 (6.4)	
	Net Weight w/o bracket, b(kg)	5.5 (2.5)		18 (8.2)		30 (13.6)		45 (20.4)		52 (23.6)		21 (9.5)		31 (14.1)		50 (22.7)	
	Shipping Weight, lb(kg)	9.6 (4.4)		28 (12.7)		60 (27.2)		75 (34)		82 (37.2)		51 (23.1)		61 (27.7)		80 (36.3)	



900 MHz Omni Antennas (890-960 MHz)

		890-960 MHz					
Model Number		DS9A06F36U3N	DS9A06F36U3D	DS9A06F36U6N	DS9A06F36U6D	DS9A10F36U3N	DS9A10F36U3D
Input Connector		N(F)	7/16 DIN	N(F)	7/16 DIN	N(F)	7/16 DIN
Type		Beamtilt		Beamtilt		Beamtilt	
ELECTRICAL	Bandwidth, MHz	70		70		70	
	Power, Watts	500		500		500	
	Gain, dBd	6		6		10	
	Horizontal Beamwidth, degrees	360		360		360	
	Vertical Beamwidth, degrees	16		16		6	
	Beam Tilt, degrees	3 Down		6 Down		3 Down	
	Isolation (minimum), dB	N/A		N/A		N/A	
MECHANICAL	Number of Connectors	1		1		1	
	Flat Plate Area, ft²(m²)	1.28 (0.12)		1.28 (0.12)		2.5 (0.23)	
	Lateral Windload Thrust, lbf(N)	48 (214)		48 (214)		122 (543)	
	Survival Wind Speed without ice, mph(kph) with 0.5” radial ice, mph(kph)	250 (402) 225 (362)		250 (402) 225 (362)		105 (169) 88 (142)	
	Mounting Hardware included	DSH2V3R		DSH2V3R		DSH3V3N	
DIMENSIONS	Length, ft(m)	6.7 (2)		6.7 (2)		16.3 (5)	
	Radome O.D., in(cm)	3 (7.6)		3 (7.6)		3 (7.6)	
	Mast O.D., in(cm)	2.5 (6.4)		2.5 (6.4)		2.5 (6.4)	
	Net Weight w/o bracket, lb(kg)	18 (8.2)		18 (8.2)		45 (20.4)	
	Shipping Weight, lb(kg)	28 (12.7)		28 (12.7)		75 (34)	

VERTICAL PATTERNS	DS9A06F36U3N DS9A06F36U3D	DS9A06F36U6N DS9A06F36U6D	DS9A10F36U3N DS9A10F36U3D



CHHT65B-C3-3XR

Multiband Antenna, 790–960, 2x 1710–2180 and 2x 2490–2690 MHz, 65° horizontal beamwidth, internal electrical tilt with individual tilt available for the 800–900, 1800–2100 and 2600 MHz bands.

- Uses the 4.3-10 connector which is 40 percent smaller than the 7-16 DIN connector

Electrical Specifications

Frequency Band, MHz	790–896	870–960	1710–1880	1850–1990	1920–2180	2490–2690
Gain, dBi	15.5	15.5	17.3	17.4	17.5	17.1
Beamwidth, Horizontal, degrees	64	63	71	69	66	60
Beamwidth, Vertical, degrees	11.2	10.3	5.6	5.4	5.1	4.3
Beam Tilt, degrees	0–10	0–10	0–8	0–8	0–8	0–8
USLS (First Lobe), dB	15	16	15	16	15	18
Front-to-Back Ratio at 180°, dB	30	30	31	29	25	26
CPR at Boresight, dB	20	19	20	20	18	16
CPR at Sector, dB	9	9	9	9	7	4
Isolation, dB	28	28	28	28	28	28
Isolation, Intersystem, dB	30	30	30	30	30	30
VSWR Return Loss, dB	1.5 14.0	1.5 14.0	1.5 14.0	1.5 14.0	1.5 14.0	1.5 14.0
PIM, 3rd Order, 2 x 20 W, dBc	-153	-153	-153	-153	-153	-150
Input Power per Port, maximum, watts	350	350	300	300	300	250
Polarization	±45°	±45°	±45°	±45°	±45°	±45°
Impedance	50 ohm	50 ohm	50 ohm	50 ohm	50 ohm	50 ohm

Electrical Specifications, BASTA*

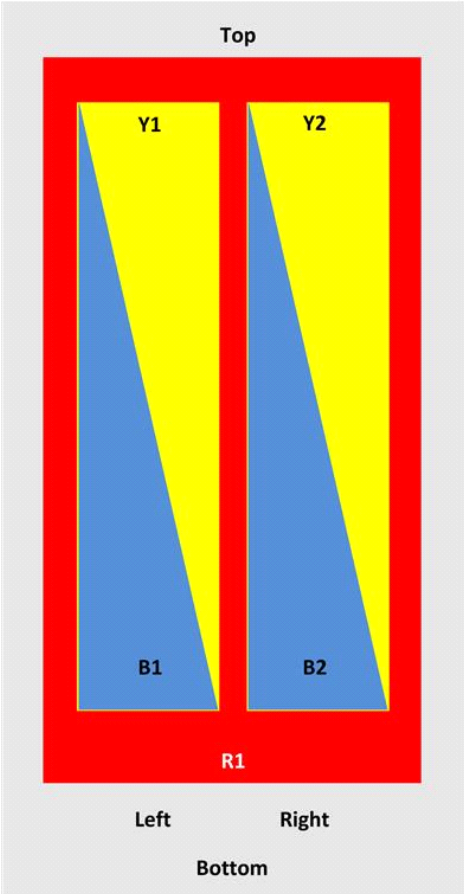
Frequency Band, MHz	790–896	870–960	1710–1880	1850–1990	1920–2180	2490–2690
Gain by all Beam Tilts, average, dBi	15.0	15.1	17.0	17.1	17.1	17.1
Gain by all Beam Tilts Tolerance, dB	±0.4	±0.3	±0.3	±0.3	±0.3	±0.6
	0 ° 15.0	0 ° 15.0	0 ° 16.8	0 ° 17.0	0 ° 17.0	0 ° 17.1
Gain by Beam Tilt, average, dBi	5 ° 15.1	5 ° 15.1	4 ° 17.0	4 ° 17.1	4 ° 17.1	4 ° 17.2
	10 ° 15.0	10 ° 15.0	8 ° 17.0	8 ° 17.1	8 ° 17.1	8 ° 17.0
Beamwidth, Horizontal Tolerance, degrees	±2.5	±1.8	±3.2	±2.7	±5	±6.6
Beamwidth, Vertical Tolerance, degrees	±0.8	±0.6	±0.2	±0.2	±0.4	±0.3
USLS, beampeak to 20° above beampeak, dB	16	17	16	17	16	19
Front-to-Back Total Power at 180° ± 30°, dB	24	26	26	25	23	23
CPR at Boresight, dB	21	20	22	22	21	16
CPR at Sector, dB	9	10	13	10	8	5

* CommScope® supports NGMN recommendations on Base Station Antenna Standards (BASTA). To learn more about the benefits of BASTA, [download the whitepaper Time to Raise the Bar on BSAs.](#)

Array Layout

CHHTT65B-C3-3XR

CHHTT65B-C3-3XR



Array	Freq (MHz)	Conns	RET (SRET)	AISG RET UID
R1	790-960	1-2	1	ANxxxxxxxxxxxxx1
B1	1710-2180	3-4	2	ANxxxxxxxxxxxxx2
B2	1710-2180	5-6		
Y1	2490-2690	7-8	3	ANxxxxxxxxxxxxx3
Y2	2490-2690	9-10		

View from the front of the antenna
(Sizes of colored boxes are not true depictions of array sizes)

General Specifications

Operating Frequency Band	1710 – 2180 MHz 2490 – 2690 MHz 790 – 960 MHz
Antenna Type	Sector
Band	Multiband
Performance Note	Outdoor usage

Mechanical Specifications

RF Connector Quantity, total	10
RF Connector Quantity, low band	2
RF Connector Quantity, high band	8
RF Connector Interface	4.3-10 Female

CHHT65B-C3-3XR

Color	Light gray
Grounding Type	RF connector inner conductor and body grounded to reflector and mounting bracket
Radiator Material	Copper Low loss circuit board
Radome Material	Fiberglass, UV resistant
Reflector Material	Aluminum
RF Connector Location	Bottom
Wind Loading, frontal	618.0 N @ 150 km/h 138.9 lbf @ 150 km/h
Wind Speed, maximum	241 km/h 150 mph

Dimensions

Length	1828.0 mm 72.0 in
Width	301.0 mm 11.9 in
Depth	181.0 mm 7.1 in
Net Weight, without mounting kit	20.2 kg 44.5 lb

Remote Electrical Tilt (RET) Information

Input Voltage	10–30 Vdc
Internal RET	High band (2) Low band (1)
Power Consumption, idle state, maximum	2.0 W
Power Consumption, normal conditions, maximum	13.0 W
Protocol	3GPP/AISG 2.0 (Single RET)
RET Interface	8-pin DIN Female 8-pin DIN Male
RET Interface, quantity	1 female 1 male

Packed Dimensions

Length	1954.0 mm 76.9 in
Width	409.0 mm 16.1 in
Depth	299.0 mm 11.8 in
Shipping Weight	32.8 kg 72.3 lb

Regulatory Compliance/Certifications

Agency	Classification
RoHS 2011/65/EU	Compliant by Exemption
China RoHS SJ/T 11364-2006	Above Maximum Concentration Value (MCV)
ISO 9001:2008	Designed, manufactured and/or distributed under this quality management system



Included Products

BSAMNT-1 — Wide Profile Antenna Downtilt Mounting Kit for 2.4 - 4.5 in (60 - 115 mm) OD round members. Kit contains one scissor top bracket set and one bottom bracket set.

CHHTT65B-C3-3XR

* Footnotes

Performance Note	Severe environmental conditions may degrade optimum performance
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dbSpectra

TECHBOOK

Series

RF FILTERS

RF Filters

RF Distribution Design

Antennas

Understanding PIM

Intermodulation

Sensitivity

Introduction

This TECHBOOK will explore the concept of filter design and how it is applied to an RF distribution system. There are several ways filters are used to enhance RF distribution designs. Filters are critical in the design of transmitter and receiver distribution systems. Transmitters must be conditioned to reduce out of band emissions and receivers require additional protection from high level carriers and interference.

What is Selectivity?

To understand filter application the concept of selectivity must be addressed. Selectivity is frequency selective attenuation and will always be related to a frequency or group of frequencies. The frequency component of selectivity is the major difference between selectivity and simple insertion loss. For a filter the insertion loss will be referenced within the passband while selectivity will be characterized outside the passband. Selectivity is also referenced in receiver specifications because receivers must have a significant frequency selectivity to allow reception of one frequency and reject others. The Selectivity of a component is provided by a curve as shown in *Figure 1*. The selectivity curve shows the frequency response of a filter with frequency as the x-axis and power level as the y-axis.

Definition of design components and terminology

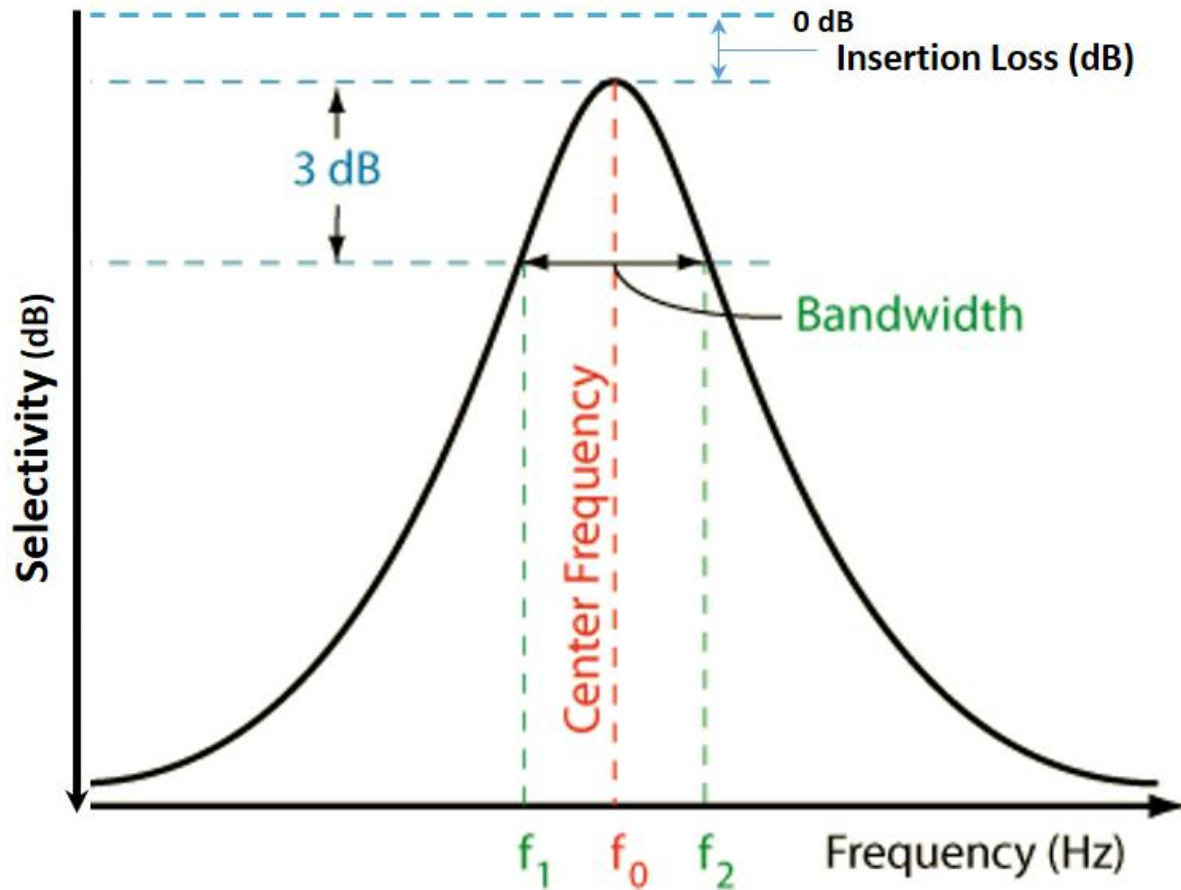


Figure 1: Definition of terminology

Cavity – The legacy building block for a frequency selective device is the cavity. While other devices provide better frequency selectivity, the cavity filter has been used for years and is still found and used on current system designs.

dB – The decibel (dB) is the increment by which the filter selectivity is measured and specified. The dB a convenient way of showing large increase or decrease in voltage or power levels. It is related to voltage or power by the base 10 logarithm. A typical range for filter measurement is 0 to -120 dB.

Center Frequency – The center frequency is the resonant frequency to which the filter is tuned. The operation of the filter is designed around the center frequency.

Insertion Loss – The insertion loss is the minimum loss of the filter and may be associated with bandpass. The insertion loss point is the tuned operating point.

Bandwidth – The operational bandwidth is generally defined by the frequency separation between the highest frequency and lowest frequency where a 3 dB insertion loss is found. In RF filters the insertion loss may be the bandwidth over which the specified insertion loss exists. The bandwidth may be wide (several MHz) as found in a bandpass filter or sharp (tens of kHz) as characterized by a single cavity. The bandwidth may also be called the passband of the filter.

Q or Quality Factor – Quality factor is used to define the selectivity of a filter with a higher value meaning higher selectivity. Mathematically, Q equals the center frequency divided by the bandwidth.

Filter Types

Bandpass Cavity – The first selectivity component we will examine is a simple band pass cavity (*Figure 2*). The bandpass cavity, sometimes called a resonator or cavity resonator, is the basic building block for many complex filter systems. A cavity is a resonant device that is tuned to one frequency or one narrow band of frequencies. At the resonant or tuned frequency, the attenuation will be minimal (normally less than 2 dB depending on the Q of the cavity). As the observed frequency increases or decreases outside the passband the attenuation increases significantly. The increase in attenuation or insertion loss is called selectivity, rejection, or isolation. While the bandpass filter is characterized by steep skirts on either side of the bandpass, the actual bandpass is normally only a few hundred kHz wide and is dependent on the Q of the filter. At the resonant frequency, the Z (impedance) will be 50 ohms and increase as the attenuation increases. Some of the unwanted energy is absorbed by the cavity, but most is reflected back to the source due to impedance

RF Filters

mismatch caused by the change in the cavity's impedance. The operation can be considered a frequency controlled variable impedance.

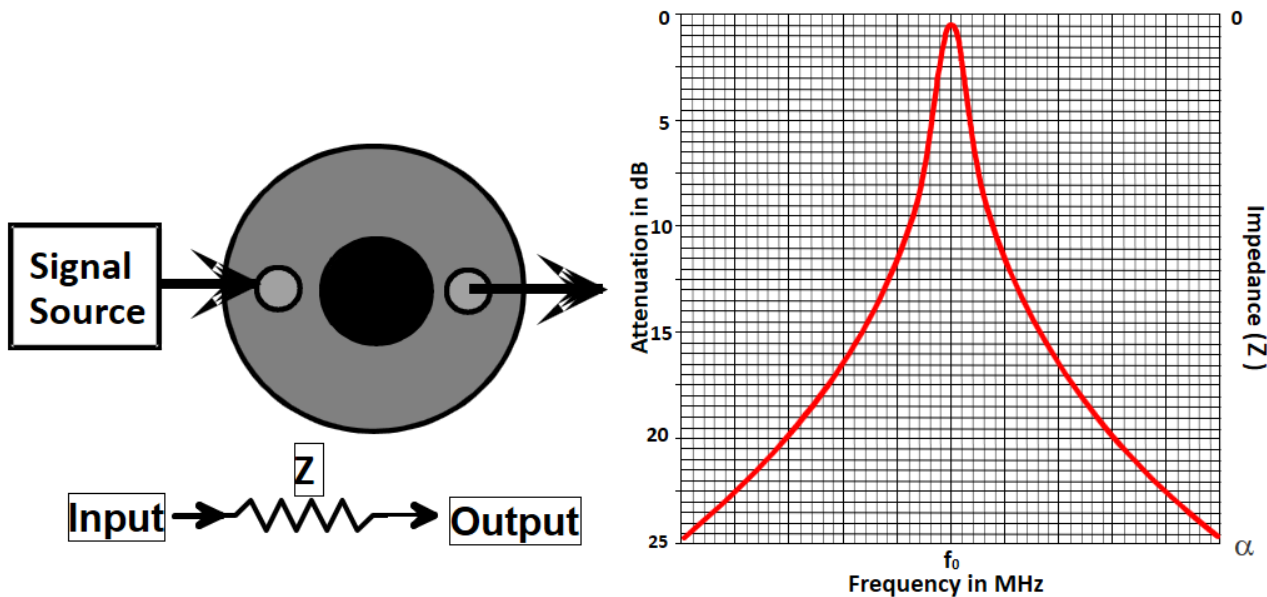


Figure 2: Fundamental characteristics of a Bandpass cavity

A single cavity is limited in the amount of obtainable selectivity. The maximum selectivity achieved is called the depth of selectivity or isolation. As the cavity selectivity is examined further and further from the center frequency the selectivity will flatten and bottom out. A rule of thumb is that a single cavity will obtain 25 – 35 dB of obtainable selectivity before it completely flattens out and stops increasing. The slope of the selectivity or how fast the selectivity increases beyond the bandpass, is controlled by the Q of the filter. As the Q is increased, the selectivity will also increase while the bandwidth decreases. For a specific filter design, increasing the Q will also increase the insertion loss of the filter.

RF Filters

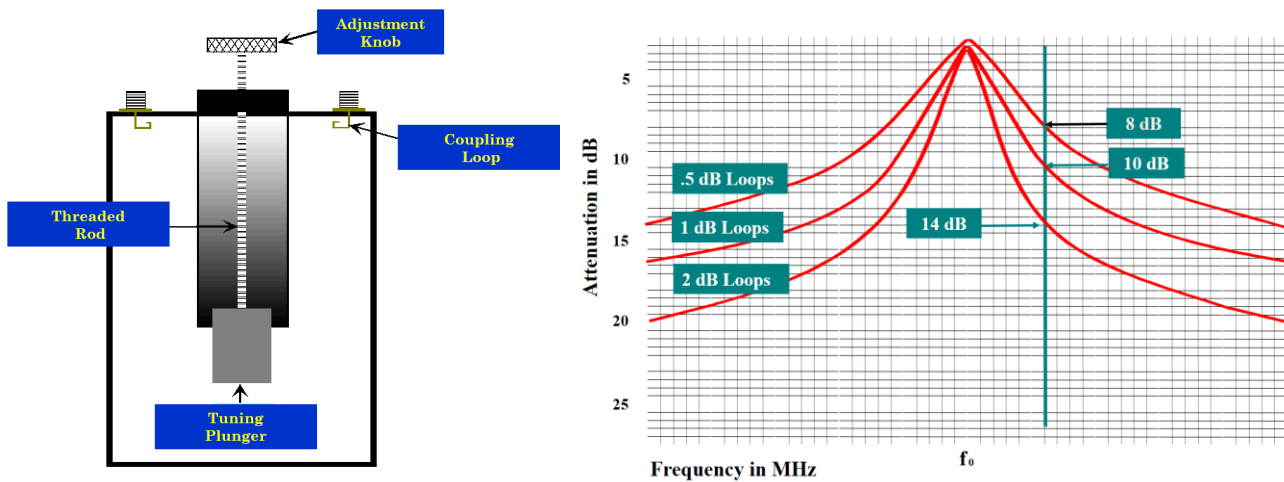


Figure 3: Selectivity vs. Q of cavity

Most cavity filters have adjustable loops. Adjusting the loops allows the Q of the cavity to be increased or decreased as needed. When the Q is increased with the loop, the Q is said to be electrically adjusted. Increasing the electrical Q of a cavity comes with an increase in insertion loss. **Figure 3** demonstrates how adjusting the loops for improved selectivity increases the insertion loss.

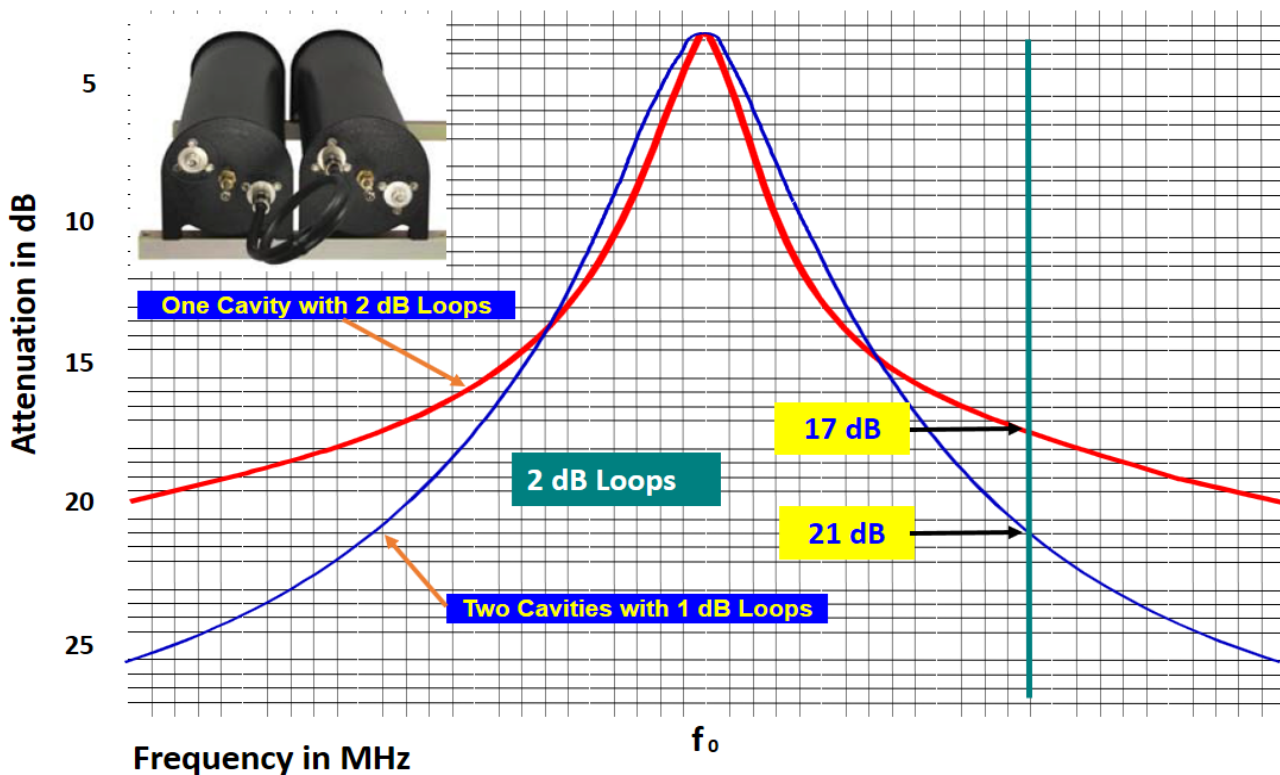


Figure 4: Multiple cavities to obtain improved selectivity

Cascading filters can improve selectivity without the penalty of greater insertion loss. Coupling multiple filters is more efficient than trying to

obtain increased selectivity in a single cavity. *Figure 4* shows that using two cavities with 1 dB loops each will provide over 21 dB of selectivity where trying to use only one cavity with 2 dB loops only delivers 17 dB of selectivity. An additional benefit in using multiple cavities is the depth of the selectivity far away from the center frequency. While the typical selectivity depth of a single filter is less than 30 dB, the depth of two cavities (with equal Q) increases to about 60 dB.

Another way to increase the Q of a cavity is to increase the volume or physical size of the cavity. This is called changing the mechanical Q . The mechanical Q is a design change not an adjustment. Larger cavities will allow improved selectivity while not significantly increasing the insertion loss. In most cases the depth of the selectivity will not change with a larger cavity. For example, dbSpectra offers VHF cavities with eight inch and five inch diameters.

Notch Cavity (*Figure 5*) – The band-reject cavity filter, or notch filter, is a high Q resonant circuit designed to attenuate a narrow band of frequencies while allowing all other frequencies to pass through with only slight attenuation. The notch filter can be considered the opposite of the band pass filter. Energy at the resonant frequencies, or center of the notch, enters the cavity and is reflected back, out of phase with the original. This creates a virtual short across the transmission line and results in a high percentage of the applied energy, at the resonate frequency, being reflected back toward the source.



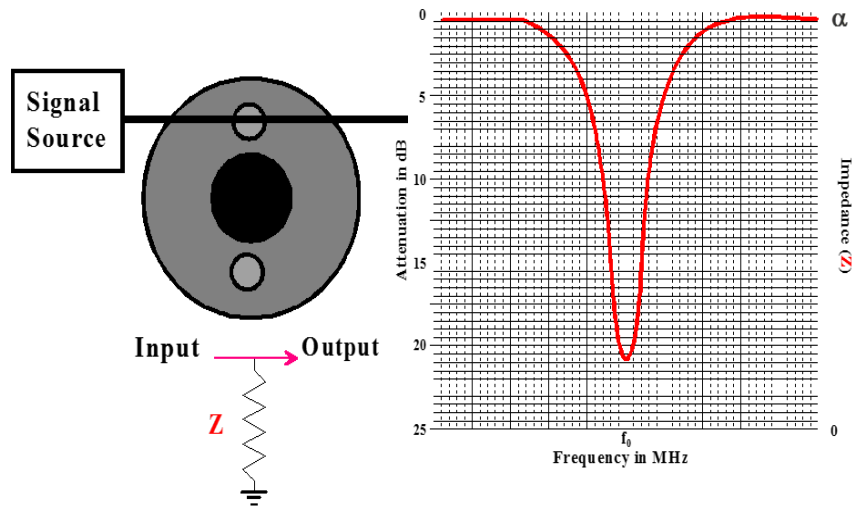


Figure 5: Notch Filter characteristic

Maximum attenuation occurs at the center (resonant) frequency while all others are attenuated to a lesser degree depending on their distance from the center frequency. At the resonant frequency, the filter has a very low impedance approaching 0 Ohms. This effectively creates a short across the line. A small amount of the energy is absorbed into the cavity and dissipated but most of the energy is reflected back to the source due to the impedance mismatch created by the near short frequency. It is very important to understand that a notch filter only provides attenuation at one frequency or one small band of frequencies. Above or below the center frequency or bandpass the filter looks like a high impedance and provides no attenuation.

The spacing between the desired frequency and the frequency to be notched or rejected can be a few megahertz or 100 KHz or less depending upon the cavity's Q . If the attenuation or slope of the selectivity obtained is not adequate, several notch filters can be cascaded to improve the depth and slope of the notch.

Pass-Reject Cavity – Another useful cavity type is the pass-reject type cavity that is capable of providing both pass and reject filter characteristics. The trade-off is that both the reject or notch depth and the bandpass response are not as pronounced as pure reject or pass type cavities.

Milled Filter Technology – The most significant advancement in filter technology over the past 30 years is the milled filter. *Figure 6* shows example Milled filters used for various applications. Milled filters get their name from the way they are constructed. Instead of individual cavities being phased together, the milled filter is computer designed from a block of aluminum which is milled out to create the housing with multiple internal cavities. Milled filters are much smaller in size, have lower insertion loss for a given selectivity, and deliver significantly more selectivity depth. The biggest disadvantage of a milled filter is that it cannot be tuned in the field.

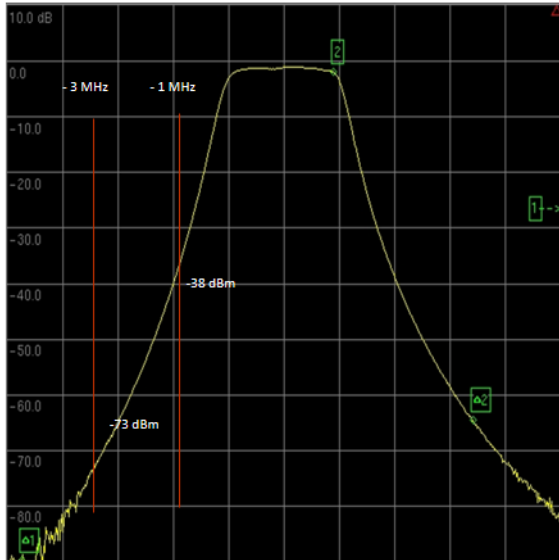


Figure 6: Milled Filter applications

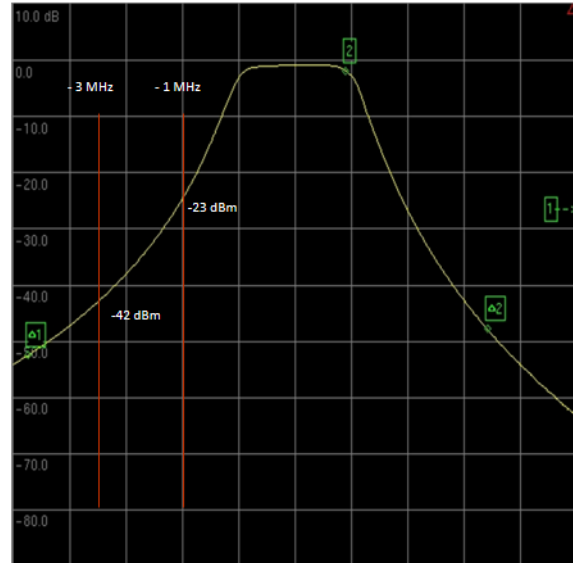
As more radios are being collocated the filter requirements have increased to allow the radios to operate without interference. *Figure 7* shows a comparison between milled filter performance and standard cavity configurations. Where a cavity provides only 25 – 30 dB of selectivity depth, the milled filter selectivity continues to increase as the off-frequency increases. The depth of selectivity can approach 100 dB

RF Filters

far away from the center frequency. It is very important to note that a milled filter cannot be field tuned. dbSpectra has led the industry in development of milled filters and offers milled filters in all bands and various applications.



New Milled Filter



Multi Cavity Preselector

Figure 7: Milled Filter vs. Standard Cavity performance curves

Not only do milled filters provided advantages compared with cavity bandpass filters but also compared with legacy filters. *Figure 8* and *Figure 9* show a comparison of legacy filters compared with a milled filter design.

RF Filters

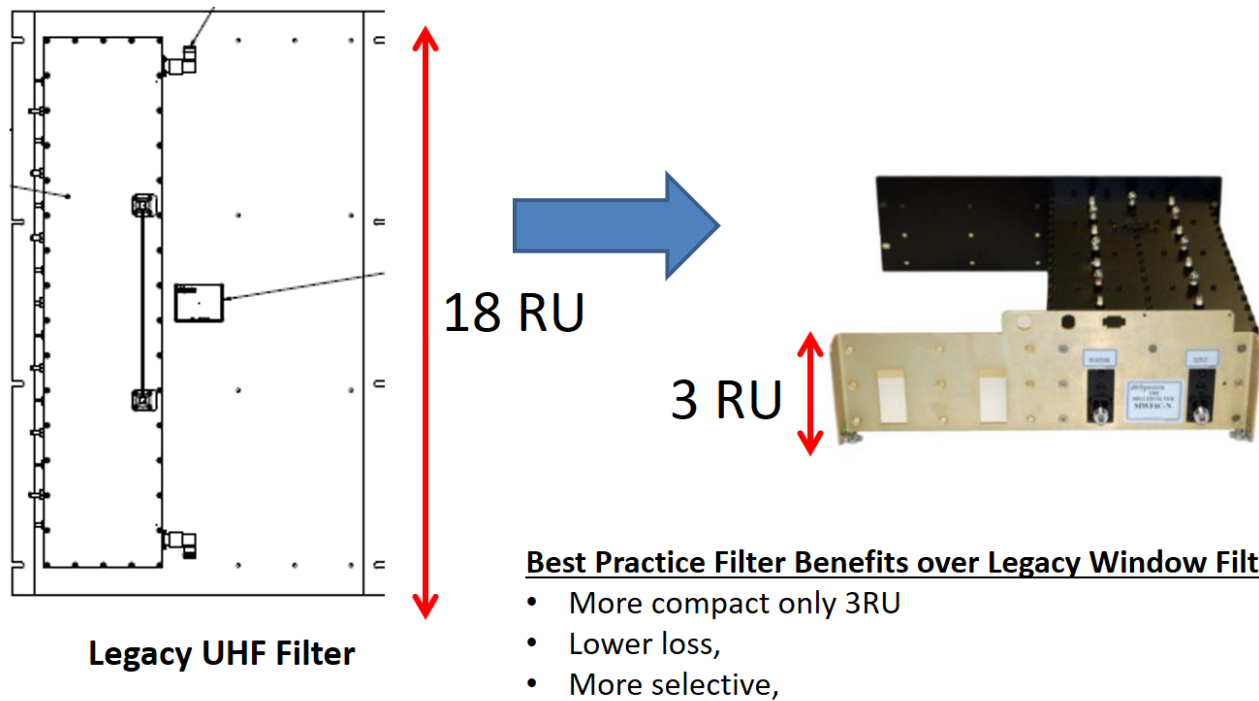


Figure 8: Bandpass milled filter compared with Legacy filter

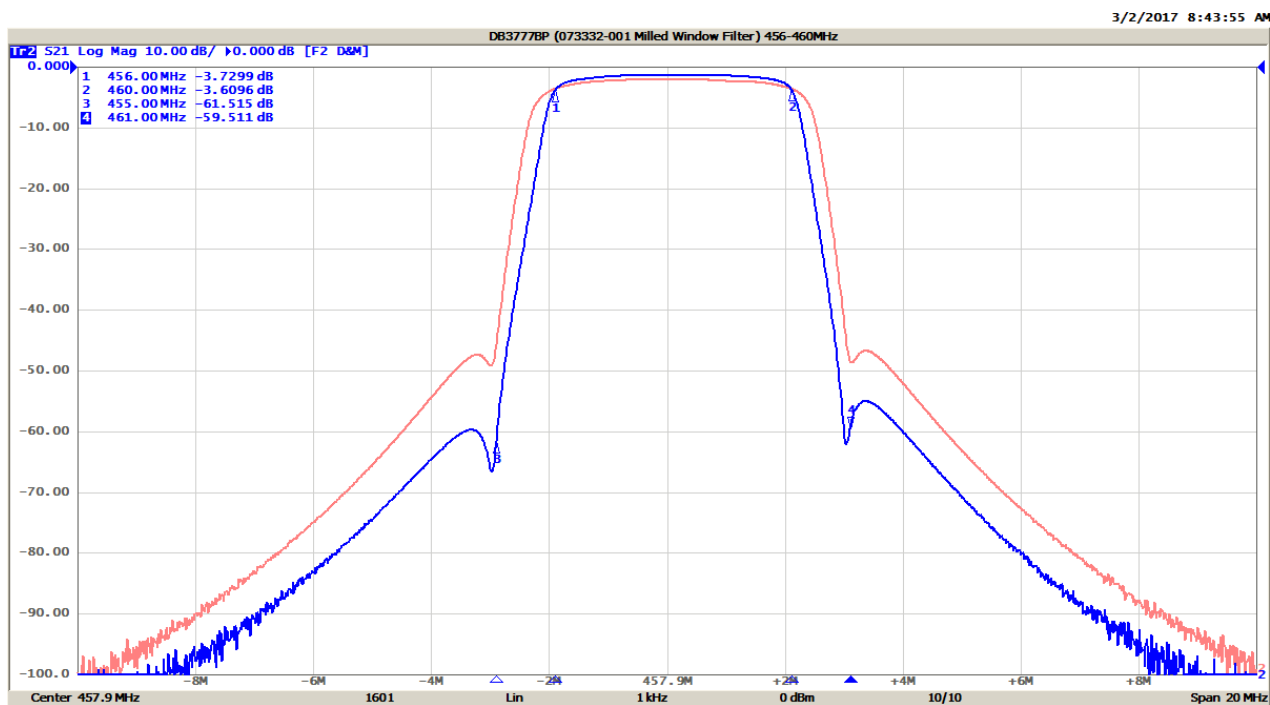


Figure 9: Bandpass Duplexer response compared with Legacy filter response

Appendix D - Power Flux Density and Power at Antenna Terminal

Power Flux Density (PFD) at ground level is the preferred metric for a harm claim threshold because it translates directly to power captured by the public safety receiver while Power Spectral Density (PSD) and ERP limits can create strong or weak power flux density on the ground depending on antenna height, topography and antenna elevation pattern. FCC precedent for 700 MHz and 800 MHz operation establishes a PFD limit of $3,000 \mu\text{W}/\text{m}^2$.¹ Our bench measurements of typical 900 MHz radios are based on power at the antenna terminal, not PFD, so a translation between PFD and power at the antenna terminal is needed. Assuming far-field plane wave propagation, a power flux density of $3,000 \mu\text{W}/\text{m}^2$ is equivalent to an electric field strength of $E = 1.06 \text{ V/m}$ (found by applying Ohm's law and assuming free space impedance of 120π). Ignoring body loss for now, the gain of a half-wave monopole on a typical portable radio is $G = 0 \text{ dBd}$ or 2.15 dBi (1.64 ratio). The antenna factor is given by

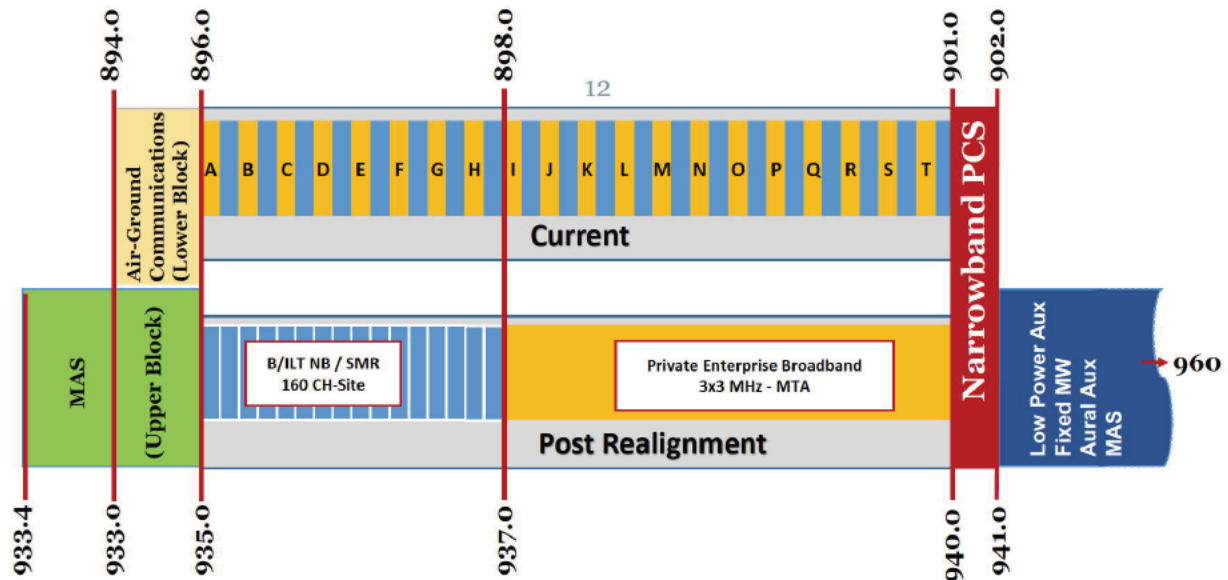
$$AF = \frac{9.73}{\lambda\sqrt{G}}$$

where λ is the radio carrier wavelength in meters (0.35 m @ 851 MHz) and G is the antenna gain (ratio). For our example, $AF = 21.7 \text{ m}^{-1}$ and the voltage at the antenna terminals is E/AF or 0.049 volts. Assuming a 50 Ohm receiver, the corresponding receive power at the antenna terminal for a PFD of $3,000 \mu\text{W}/\text{m}^2$ is -13.2 dBm. If a PFD per MHz standard is adopted at 900 MHz, the maximum power at the antenna terminal would be 5 dB (factor of 3) stronger, or -8.2 dBm.

¹ Actually, the standard in § 22.913 is PFD per MHz, but the receiver reacts to total power more so than power density, so we prefer a purely PFD limit on a per sector basis. See Pericle's filing in the WT Docket 12-40 proceeding, December 4, 2015.

EXHIBIT B

Comparison of Downlink Out-of-Band Emissions (OOBE) Between a Notional LTE Network and a Full or Partially Built- Out Part 90 Narrowband System



November 1, 2017

Prepared for:

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Comparison of Downlink Out-of-Band Emissions (OOBE) Between a Notional LTE Network and a Full or Partially Built-Out Part 90 Narrowband System

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1.0 Background. Some commenters on the WT Docket 17-200 have expressed concern that downlink OOBE from a new 3 MHz LTE radio carrier operating between 937 and 940 MHz will create harmful interference to either Part 90 incumbents operating in the 935-937 MHz sub band or Narrowband PCS incumbents operating in the 940-941 MHz band, interference which some incumbents claim does not exist today. But comparison between the prospective LTE carrier and the artificially quiet conditions existing today in the band is not valid in the long term nor is such a quiet state guaranteed by the FCC. Rather than compare to the interference environment of today, one should compare to a fully built-out 900 MHz band because such a state is the logical best use of the band in the absence of a rule change to allow broadband use. Accordingly, this study computes the $C/(I+N)$ for two cases and compares the difference in potentially affected area for both cases:

- Case 1 is identical to the Pericle LTE white paper case [1] and based on an emission mask limit of $55+10\log(P)$ (measured in 30 kHz) at the 3 MHz channel edge for three markets: San Antonio, Orlando and San Diego. This emission limit is equivalent to -25 dBm.
- Case 2 is a prospective fully built-out network with three tall sites assuming protection based on the § 90.210 Mask I with an OOBE limit of $43+10\log(P)$, 12 dB greater than the LTE case, for the same three markets. This emission limit is equivalent to -13 dBm.

At a high level, the LTE network operates from more sites than typical Part 90 systems (6 or 7 versus 3) and operates from lower antenna height (30 meters versus 64.9 meters), but the emission mask is 12 dB lower. On the other hand, the narrowband Part 90 network(s) operate with many more carriers (there are 399 channels in the band). Also, the emission mask proposed by PDV requires emissions 12 dB lower for the LTE carrier as compared to the Part 90 transmission.

This modeling study weights each analysis factor in accordance with real-world conditions to quantify the potential interference in each case, using the three markets as case studies.

2.0 Assumptions. The following assumptions are used:

LTE carrier emission mask limit = $55 + 10\log(P)$ measured in 30 kHz

Other LTE network assumptions, including propagation model = per white paper [1]

Part 90 narrowband (12.5 kHz) emission mask limit = $43 + 10\log(P)$ in 30 kHz¹

Number of narrowband sites = 3

Active transmitters per site = 50 (150 total in the market out of 399 available channels in the band)

Narrowband antenna height = 64.9 meters AGL (average height of incumbents in the markets)

Minimum required $C/(I+N)$ = 17 dB (from § 90.672).

Note that there are 399 12.5 kHz-wide channels in the 935-940 MHz band. We are assuming 50 channels per site (e.g., 16-17 channels per sector for a sectorized system) as a simplified model of *all* active transmitters in the market. We believe this assumption is conservative, even accounting for trunking inefficiencies, because these 150 total channels account for less than 38% of the available channels in the market.

3.0 Results. In addition to analyzing the effect of 50 active transmitters per site, we also computed other cases to determine the number of active transmitters required to create roughly the same downlink interference impact as the single LTE carrier (from the white paper [1]). Results are shown in Table 1. We see from Table 1 that a fully built-out Part 90 narrowband system creates an order of magnitude (factor of 10) or more interference in terms of area affected than an LTE system. Furthermore, the breakeven point with the LTE network in terms of potential area affected is much lower than the fully built-out assumption of 50 channels per site. It is between 3 and 8 channels per site, equivalent to a very lightly loaded network. In other words, a network well less than a fully built-out state will create greater downlink OOB interference than the prospective LTE network.

Table 1 - $C/(I+N)$ Less Than 17 dB Due to Downlink OOB				
		LTE Carrier (white paper)	Active TX for Part 90 Mask 1 Equivalent (Breakeven)	Fully Built-Out Part 90 Network (50 TX/Site)
Market	Incumbent	Area Affected	Number of Transmitters	Area Affected
San Antonio, TX	LCRA	0.65%	5	5.6%
Orlando, FL	Duke Energy	0.041%	8	0.71%
San Diego, CA	SDG&E	0.11%	3	3.3%

Plots of $C/(I+N)$ for the LTE case and the fully built-out narrowband case are found in Appendix A. A list of Part 90 900 MHz incumbent licensees in each market is found in Appendix B. Note from Appendix B that there are a significant number of emitters already operating in each market, each creating potential downlink OOB interference even today.

¹ We are assuming a minimally compliant system in each case with the emission mask limit applying to the channel edge for the LTE radio carrier and at 15 kHz from channel center for the narrowband radio carrier.

4.0 Uplink OOB. We expect the uplink conclusions to be similar. One additional factor in LTE's favor as compared to the Part 90 narrowband system is that the LTE system uses power control in the handsets with at least a 9 dB back off over 98% of the time (urban/suburban) [2] while the narrowband user handset typically operates at full power whenever keyed. Because there is an equivalent reduction in OOB directly proportional (in dB) to the power back-off [3], in most cases the OOB from an LTE handset will be no worse and in many cases less than that from a Part 90 handset.

5.0 Conclusion. A fully built-out narrowband network is the only valid state for incumbents to compare to because it is the economically best use of the band in the absence of a broadband allocation. When we compare the prospective LTE network to a fully built-out narrowband system (or systems) we see that the narrowband system creates more downlink out-of-band emissions interference than the LTE system by a wide margin. But even a lightly-loaded network (well less than a full build out) creates as much interference as the LTE network. Thus, we can conclude that the LTE network is likely to create *less* interference than the next best alternative, not more.

This conclusion holds even after the band is reconfigured. Although Part 90 narrowband systems will occupy a smaller portion of the band, the rules would continue to allow full loading of all available channels. And as shown here, the out-of-band emissions from the LTE network would be less than that created by only a handful of Part 90 transmitters operating in that same spectrum.

6.0 References

- [1] J. M. Jacobsmeyer, "Technical Impacts of a 900 MHz Private Enterprise Broadband Allocation," September 29, 2017, submitted comments on WT 17-200.
- [2] Commerce Spectrum Management Advisory Committee (CSMAC) Final Report: Working Group 1 – 1695-1710 MHz Meteorological-Satellite, Appendix 3: Baseline LTE Uplink Characteristics, January 22, 2013.
- [3] 3GPP TSG-RAN4 #59AH, R4-113745, B26 Uplink LTE UE to PS BS co-existence, Bucharest, Romania, 27th June to 1st July, 2011.

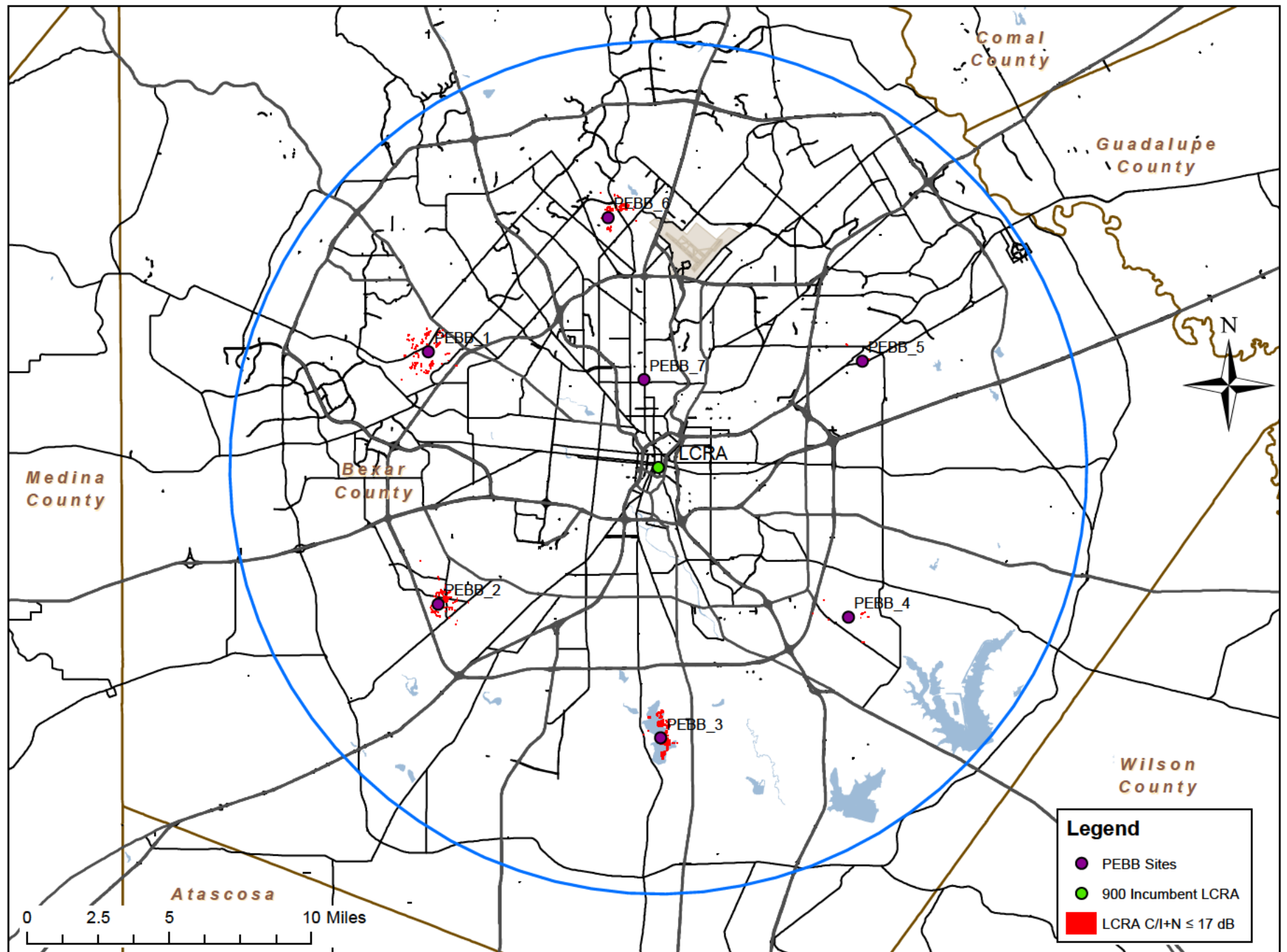
Appendices:

Appendix A - Plots of $C/(I+N) \leq 17$ dB in each market for each emission mask case (3 markets, 6 plots total). Note that incumbent sites other than victim sites not shown for clarity of presentation.

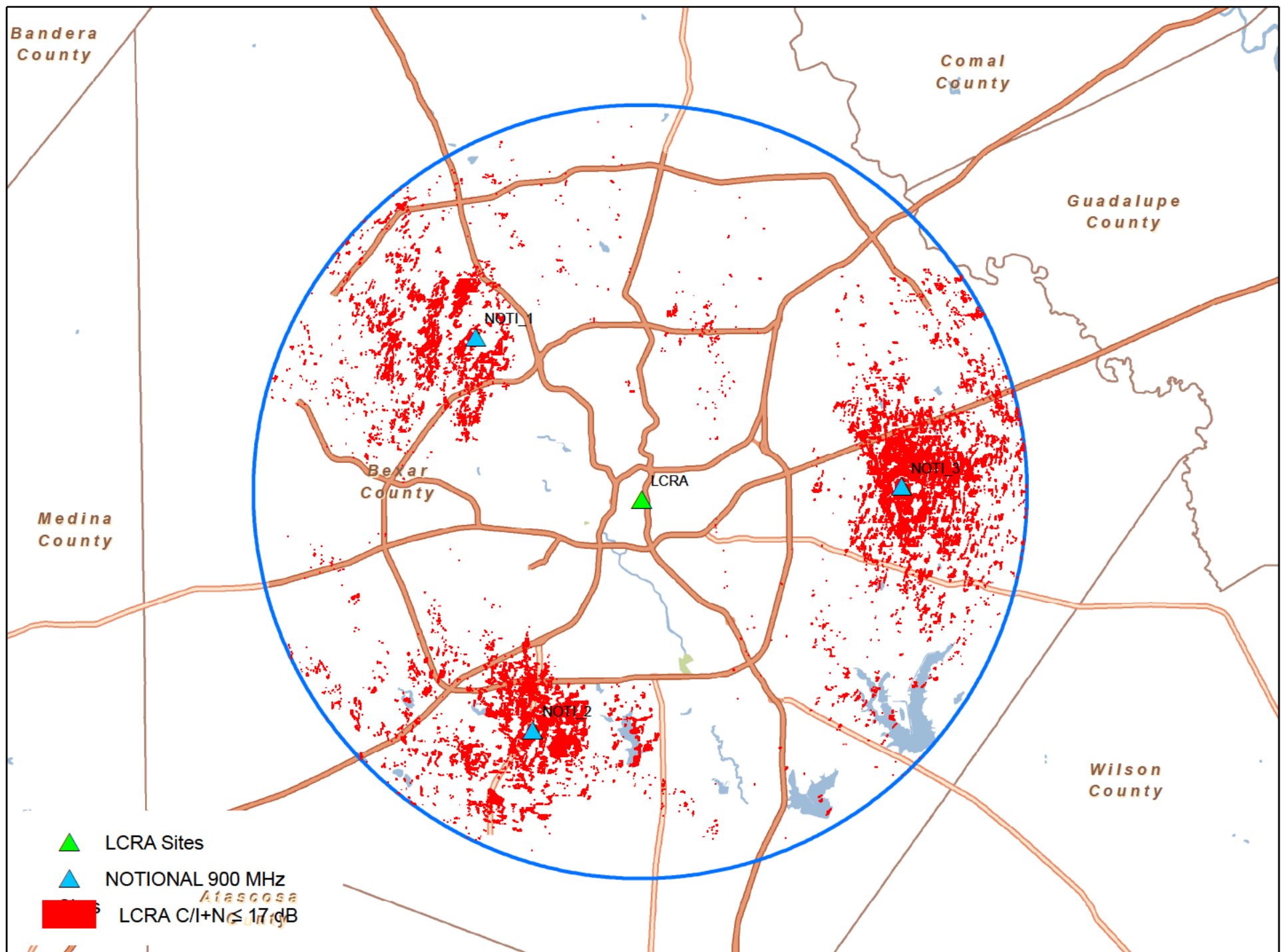
Appendix B - List of incumbent 900 MHz licensees within 15 miles of city center for each of three markets.

Appendix A - Downlink OOB Interference Plots for Two Cases in Three Markets

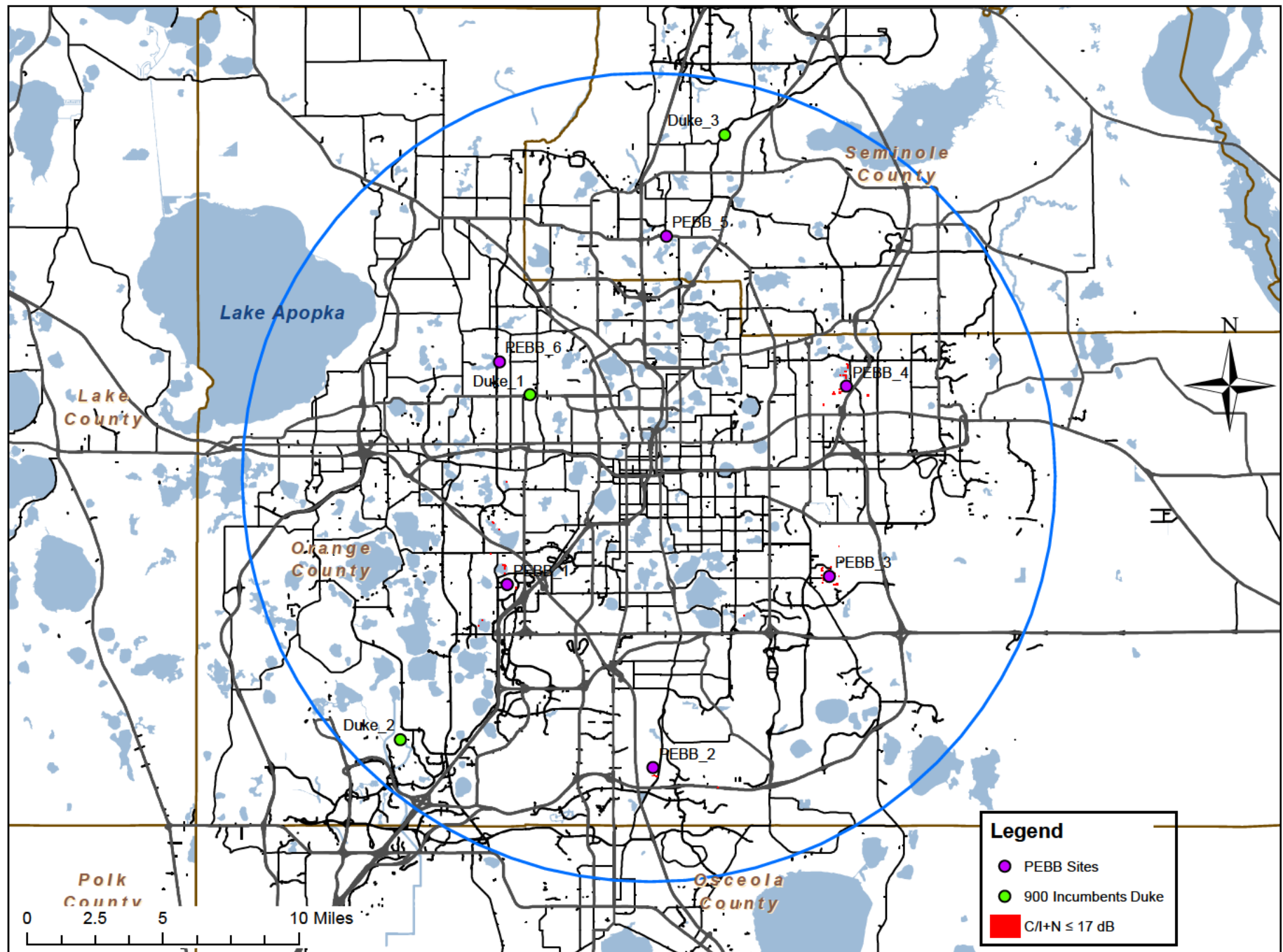
LCRA LTE Downlink Interference



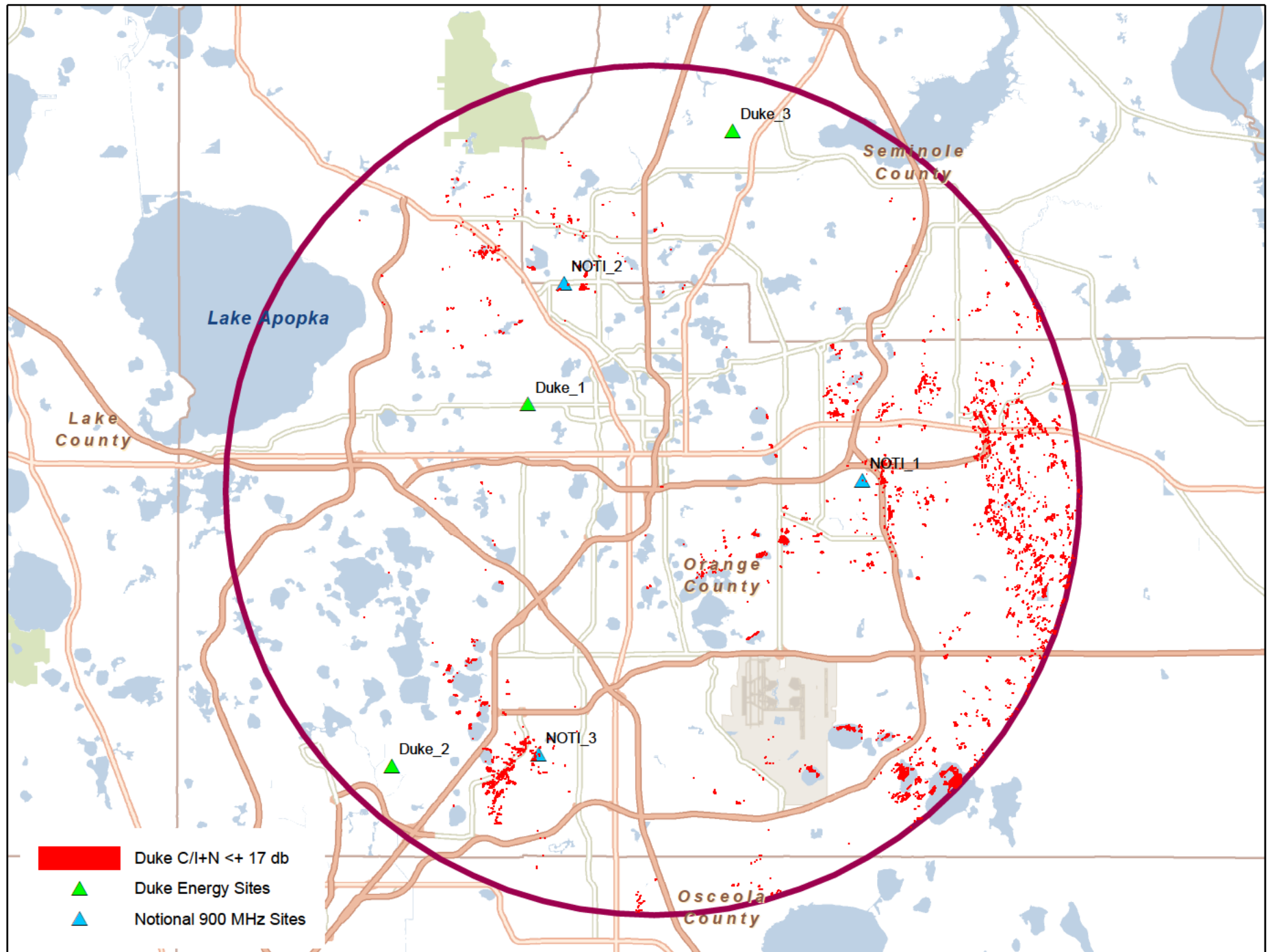
50 Channel Notional 900 MHz NB 3 Site Interference to LCRA



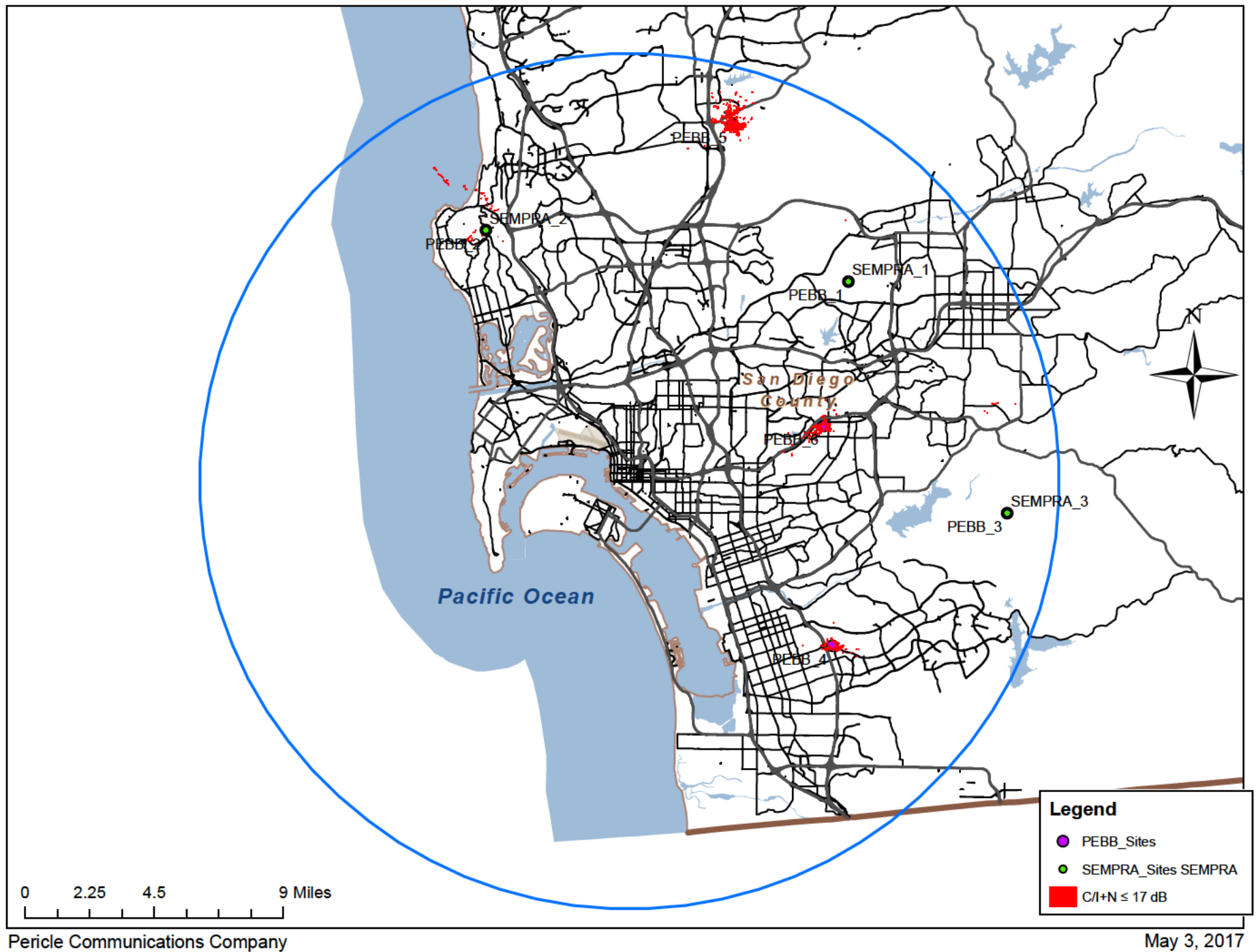
Duke Energy LTE Downlink Interference



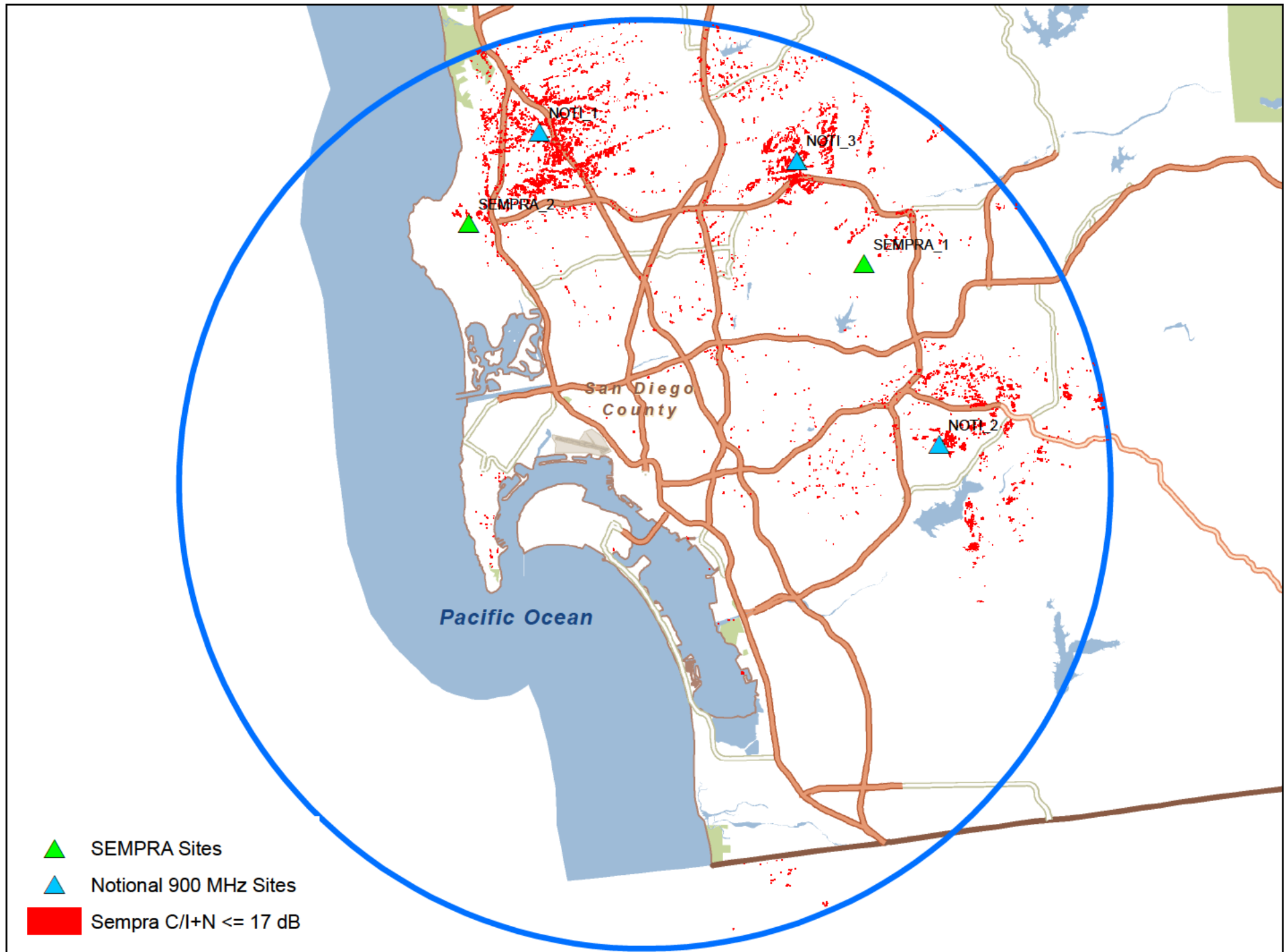
50 Channel Notional 900 MHz NB 3 Site Interference to Duke Energy



SEMPRA LTE Downlink Interference



50 Channel Notional 900 MHz NB 3 Site Interference to SEMPRA



Appendix B - Part 90 900 MHz Incumbent Licensees in Three Markets

San Antonio, TX 900 MHz Licensees within 15 miles of City Center

4/23/17												
CallSign	Licensee	Radio Service	Freq	Loc Address	Lo City	LatDeg	LatMin	LatSec	LonDeg	LonMin	LonSec	Miles to Core San Antonio (mi)
WPWW828	AAA TEXAS LLC	GU	935.1875	310 S SAINT MARYS ST	SAN ANTONIO	29	25	22	98	29	29	0.140000001
WPWW828	AAA TEXAS LLC	GU	935.1875	310 S SAINT MARYS ST	SAN ANTONIO	29	25	22	98	29	29	0.140000001
WQBB243	PDV Spectrum Holding Company, LLC	GR	936.1375	310 S SAINT MARYS ST	SAN ANTONIO	29	25	22	98	29	29	0.140000001
WPWW828	AAA TEXAS LLC	GU	935.1875	112 EAST PECAN BLVD.	SAN ANTONIO	29	25	42	98	29	33	0.310000002
WPWW828	AAA TEXAS LLC	GU	935.1875	112 EAST PECAN BLVD.	SAN ANTONIO	29	25	42	98	29	33	0.310000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	935.15	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	935.2125	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	935.2375	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	935.7125	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	936.4375	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	938.225	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	939.4	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	939.4375	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	939.4875	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	939.6375	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	939.65	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	939.6625	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	939.7	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	939.7375	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	939.75	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WPXU562	LOWER COLORADO RIVER AUTHORITY	YI	939.95	889 E. MARKET STREET	SAN ANTONIO	29	25	19.3	98	29	3.6	0.560000002
WQTC271	Dailey and Wells Communications Inc	YS	935.9125	610 East Market St	San Antonio	29	25	18.5	98	29	0	0.620000005
WQTC271	Dailey and Wells Communications Inc	YS	936.25	610 East Market St	San Antonio	29	25	18.5	98	29	0	0.620000005
WQTC271	Dailey and Wells Communications Inc	YS	936.4875	610 East Market St	San Antonio	29	25	18.5	98	29	0	0.620000005
WQTC271	Dailey and Wells Communications Inc	YS	936.975	610 East Market St	San Antonio	29	25	18.5	98	29	0	0.620000005
WQTC271	Dailey and Wells Communications Inc	YS	937.7125	610 East Market St	San Antonio	29	25	18.5	98	29	0	0.620000005
WQTC271	Dailey and Wells Communications Inc	YS	937.9375	610 East Market St	San Antonio	29	25	18.5	98	29	0	0.620000005
WQTC271	Dailey and Wells Communications Inc	YS	938.725	610 East Market St	San Antonio	29	25	18.5	98	29	0	0.620000005
WQTC271	Dailey and Wells Communications Inc	YS	938.9	610 East Market St	San Antonio	29	25	18.5	98	29	0	0.620000005
WQTC271	Dailey and Wells Communications Inc	YS	939.1375	610 East Market St	San Antonio	29	25	18.5	98	29	0	0.620000005
WQTC271	Dailey and Wells Communications Inc	YS	939.9	610 East Market St	San Antonio	29	25	18.5	98	29	0	0.620000005
WQTX719	Community Arena Management	YS	935.225	1 AT&T CENTER PKWY	SAN ANTONIO	29	25	39.2	98	26	16.7	3.349999905
WQTX719	Community Arena Management	YS	935.4	1 AT&T CENTER PKWY	SAN ANTONIO	29	25	39.2	98	26	16.7	3.349999905
WQTX719	Community Arena Management	YS	935.7375	1 AT&T CENTER PKWY	SAN ANTONIO	29	25	39.2	98	26	16.7	3.349999905
WQTX719	Community Arena Management	YS	936.5	1 AT&T CENTER PKWY	SAN ANTONIO	29	25	39.2	98	26	16.7	3.349999905
WQTX719	Community Arena Management	YS	937.4625	1 AT&T CENTER PKWY	SAN ANTONIO	29	25	39.2	98	26	16.7	3.349999905
WQTX719	Community Arena Management	YS	937.65	1 AT&T CENTER PKWY	SAN ANTONIO	29	25	39.2	98	26	16.7	3.349999905
WQTX719	Community Arena Management	YS	938.4125	1 AT&T CENTER PKWY	SAN ANTONIO	29	25	39.2	98	26	16.7	3.349999905
WQTX719	Community Arena Management	YS	938.7375	1 AT&T CENTER PKWY	SAN ANTONIO	29	25	39.2	98	26	16.7	3.349999905
WQTX719	Community Arena Management	YS	938.9375	1 AT&T CENTER PKWY	SAN ANTONIO	29	25	39.2	98	26	16.7	3.349999905
WQTX719	Community Arena Management	YS	939.2375	1 AT&T CENTER PKWY	SAN ANTONIO	29	25	39.2	98	26	16.7	3.349999905
WNPS264	PDV Spectrum Holding Company, LLC	YS	935.5125	7 MI W IH 10 2.6 MI B HWT	SAN ANTONIO	29	38	0.8	98	37	51.1	16.64999962
WNPS264	PDV Spectrum Holding Company, LLC	YS	935.525	7 MI W IH 10 2.6 MI B HWT	SAN ANTONIO	29	38	0.8	98	37	51.1	16.64999962
WNPS264	PDV Spectrum Holding Company, LLC	YS	935.5375	7 MI W IH 10 2.6 MI B HWT	SAN ANTONIO	29	38	0.8	98	37	51.1	16.64999962
WNPS264	PDV Spectrum Holding Company, LLC	YS	935.55	7 MI W IH 10 2.6 MI B HWT	SAN ANTONIO	29	38	0.8	98	37	51.1	16.64999962
WNPS264	PDV Spectrum Holding Company, LLC	YS	935.5625	7 MI W IH 10 2.6 MI B HWT	SAN ANTONIO	29	38	0.8	98	37	51.1	16.64999962
WNPS264	PDV Spectrum Holding Company, LLC	YS	935.575	7 MI W IH 10 2.6 MI B HWT	SAN ANTONIO	29	38	0.8	98	37	51.1	16.64999962
WNPS264	PDV Spectrum Holding Company, LLC	YS	935.5875	7 MI W IH 10 2.6 MI B HWT	SAN ANTONIO	29	38	0.8	98	37	51.1	16.64999962
WNPS264	PDV Spectrum Holding Company, LLC	YS	935.6	7 MI W IH 10 2.6 MI B HWT	SAN ANTONIO	29	38	0.8	98	37	51.1	16.64999962
WNPS264	PDV Spectrum Holding Company, LLC	YS	935.6125	7 MI W IH 10 2.6 MI B HWT	SAN ANTONIO	29	38	0.8	98	37	51.1	16.64999962
WNPS264	PDV Spectrum Holding Company, LLC	YS	935.625	7 MI W IH 10 2.6 MI B HWT	SAN ANTONIO	29	38	0.8	98	37	51.1	16.64999962
WPWW828	AAA TEXAS LLC	GU	935.1875	8023 VANTAGE	SAN ANTONIO	29	39	41.8	98	32	46.1	16.68000031
WPWW828	AAA TEXAS LLC	GU	935.1875	8023 VANTAGE	SAN ANTONIO	29	39	41.8	98	32	46.1	16.68000031

4/23/17

Callsign	Licensee	Radio Service	Loc Type	Loc Address	Lo City	Loc ST	LatDeg	LatMin	LatSec	LonDeg	LonMin	LonSec	Miles to Core Orlando (mi)
WPTP846	FleetTalk Partners, Ltd.	GR	F	633 N Orange Ave	Orlando	FL	28	32	54	81	22	45	0.709999979
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4781 W COLONIAL DR	ORLANDO	FL	28	33	20	81	26	32.3	4.010000229
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4781 W COLONIAL DR	ORLANDO	FL	28	33	20	81	26	32.3	4.010000229
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4781 W COLONIAL DR	ORLANDO	FL	28	33	20	81	26	32.3	4.010000229
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4781 W COLONIAL DR	ORLANDO	FL	28	33	20	81	26	32.3	4.010000229
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4781 W COLONIAL DR	ORLANDO	FL	28	33	20	81	26	32.3	4.010000229
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4781 W COLONIAL DR	ORLANDO	FL	28	33	20	81	26	32.3	4.010000229
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WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4781 W COLONIAL DR	ORLANDO	FL	28	33	20	81	26	32.3	4.010000229
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WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4781 W COLONIAL DR	ORLANDO	FL	28	33	20	81	26	32.3	4.010000229
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4781 W COLONIAL DR	ORLANDO	FL	28	33	20	81	26	32.3	4.010000229
WPTQ574	Duke Energy Business Services, LLC	YI	F	WOODSMERE MW BLDG	ORLANDO	FL	28	34	42	81	27	21	5.409999847
WPTQ574	Duke Energy Business Services, LLC	YI	F	WOODSMERE MW BLDG	ORLANDO	FL	28	34	42	81	27	21	5.409999847
WPTQ574	Duke Energy Business Services, LLC	YI	F	WOODSMERE MW BLDG	ORLANDO	FL	28	34	42	81	27	21	5.409999847
WPTQ574	Duke Energy Business Services, LLC	YI	F	WOODSMERE MW BLDG	ORLANDO	FL	28	34	42	81	27	21	5.409999847
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
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WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	N SIDE OF 6003 PERSHING AVE	ORLANDO	FL	28	30	5	81	17	59.2	5.460000038
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4850 WEST OAKRIDGE ROAD	ORLANDO	FL	28	28	15.3	81	26	30.6	5.980000019
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4850 WEST OAKRIDGE ROAD	ORLANDO	FL	28	28	15.3	81	26	30.6	5.980000019
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WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4850 WEST OAKRIDGE ROAD	ORLANDO	FL	28	28	15.3	81	26	30.6	5.980000019
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WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4850 WEST OAKRIDGE ROAD	ORLANDO	FL	28	28	15.3	81	26	30.6	5.980000019
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4850 WEST OAKRIDGE ROAD	ORLANDO	FL	28	28	15.3	81	26	30.6	5.980000019
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4850 WEST OAKRIDGE ROAD	ORLANDO	FL	28	28	15.3	81	26	30.6	5.980000019
WPB 820	ORLANDO UTILITIES COMMISSION	YI	F	4850 WEST OAKRIDGE ROAD	ORLANDO	FL	28	28	15.3	81	26	30.6	5.980000019
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	6.5
WQSI773	UNIVERSAL CITY DEVELOPMENT PARTNERS, LTD	YI	F	1000 UNIVERSAL STUDIOS PLZ KING BLDG	ORLANDO	FL	28	29	0	81	27	59.3	

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San Diego, CA 900 MHz Licensees within 15 miles of City Center

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CallSign	Licensee	Radio Service	Freq	LO Address	LO City	LO ST	LatDeg	LatMin	LatSec	LonDeg	LonMin	LonSec	Miles to Core San Deigo (mi)
WPNS268	PDV Spectrum Holding Company, LLC	GR	935.675	CORONADO SHORES	CORONADO	CA	32	40	33.2	117	10	25.1	2.890000105
WPNS268	PDV Spectrum Holding Company, LLC	GR	938.2125	CORONADO SHORES	CORONADO	CA	32	40	33.2	117	10	25.1	2.890000105
WPRL243	PDV Spectrum Holding Company, LLC	GR	938.7	CORONADO SHORES	CORONADO	CA	32	40	33.2	117	10	25.1	2.890000105
WPNP203	PDV Spectrum Holding Company, LLC	GR	938.7125	CORONADO SHORES	CORONADO	CA	32	40	33.2	117	10	25.1	2.890000105
WPR 760	PDV Spectrum Holding Company, LLC	GR	937.75	MT SOLEDAD-PRIMARY	LA OLLA	CA	32	49	59.2	117	15	1.1	9.789999962
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.1375	6902 BARKER WAY	SAN DIEGO	CA	32	48	49	117	1	53	9.939999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.15	6902 BARKER WAY	SAN DIEGO	CA	32	48	49	117	1	53	9.939999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.1625	6902 BARKER WAY	SAN DIEGO	CA	32	48	49	117	1	53	9.939999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.175	6902 BARKER WAY	SAN DIEGO	CA	32	48	49	117	1	53	9.939999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.1875	6902 BARKER WAY	SAN DIEGO	CA	32	48	49	117	1	53	9.939999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.2	6902 BARKER WAY	SAN DIEGO	CA	32	48	49	117	1	53	9.939999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.225	6902 BARKER WAY	SAN DIEGO	CA	32	48	49	117	1	53	9.939999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.675	6902 BARKER WAY	SAN DIEGO	CA	32	48	49	117	1	53	9.939999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	937.3875	6902 BARKER WAY	SAN DIEGO	CA	32	48	49	117	1	53	9.939999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.1375	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.15	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.1625	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.175	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUK840	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.175	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.1875	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUK840	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.2	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.2	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUK840	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.225	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.225	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUK840	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.2375	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUK840	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.25	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUK840	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.675	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.675	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUK840	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.725	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	937.3875	7700 LA OLLA SCENIC DRIVE SOUTH	LA OLLA	CA	32	50	17	117	14	57	10.039999996
WPMM989	MANHOLE AD USTING CONTRACTORS	GU	937.2	ATOP MT SAN MIGUEL	SPRING VALLEY	CA	32	41	46.2	116	56	12.1	12.86999998
WPDA453	AUTOMOBILE CLUB OF SOUTHERN CALIFORNIA	GU	937.675	ATOP MOUNT SAN MIGUEL	SAN DIEGO	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company, LLC	YS	935.3875	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WP G607	PDV Spectrum Holding Company, LLC	GR	935.475	MOUNT SAN MIGUEL	SAN DIEGO	CA	32	41	47.2	116	56	9.1	12.90999985
WQB 574	PDV Spectrum Holding Company, LLC	YS	935.6875	Atop San Miguel Mtn.	San Diego	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company, LLC	YS	935.7125	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company LLC	YS	935.725	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WQB 574	PDV Spectrum Holding Company, LLC	YS	935.7375	Atop San Miguel Mtn.	San Diego	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company, LLC	YS	936.4375	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company, LLC	YS	936.45	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company, LLC	YS	936.4625	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company, LLC	YS	936.475	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company, LLC	YS	936.4875	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company, LLC	YS	936.5	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WQB 574	PDV Spectrum Holding Company, LLC	YS	936.6875	Atop San Miguel Mtn.	San Diego	CA	32	41	47.2	116	56	9.1	12.90999985
WQB 574	PDV Spectrum Holding Company, LLC	YS	936.7	Atop San Miguel Mtn.	San Diego	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company LLC	YS	936.925	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WQB 574	PDV Spectrum Holding Company, LLC	YS	937.15	Atop San Miguel Mtn.	San Diego	CA	32	41	47.2	116	56	9.1	12.90999985
WQB 574	PDV Spectrum Holding Company, LLC	YS	937.1625	Atop San Miguel Mtn.	San Diego	CA	32	41	47.2	116	56	9.1	12.90999985
WQB 574	PDV Spectrum Holding Company, LLC	YS	937.2125	Atop San Miguel Mtn.	San Diego	CA	32	41	47.2	116	56	9.1	12.90999985
WPPU369	PDV Spectrum Holding Company, LLC	GR	937.425	SAN MIGUEL	S SAN DIEGO	CA	32	41	47.2	116	56	9.1	12.90999985
WPPU370	PDV Spectrum Holding Company, LLC	GR	937.425	SAN MIGUEL	S SAN DIEGO	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company, LLC	YS	937.45	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company, LLC	YS	937.4625	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WPKT732	PDV Spectrum Holding Company, LLC	YS	937.475	MOUNT SAN MIGUEL	POWAY	CA	32	41	47.2	116	56	9.1	12.90999985
WQB 574	PDV Spectrum Holding Company, LLC	YS	937.6625	Atop San Miguel Mtn.	San Diego	CA	32	41	47.2	116	56	9.1	12.90999985
WPPA341	PDV Spectrum Holding Company LLC	GR	938.7125	ATOP SAN MIGUEL	SAN DIEGO	CA	32	41	47.2	116	56	9.1	12.90999985
WQUW935	VEGAS WIRELESS LLC	YI	938.975	SAN MIGUEL MOUNTAIN	SAN DIEGO	CA	32	41	47.2	116	56	9.1	12.90999985
WQUW935	VEGAS WIRELESS LLC	YI	938.9875	SAN MIGUEL MOUNTAIN	SAN DIEGO	CA	32	41	47.2	116	56	9.1	12.90999985
WQUW935	VEGAS WIRELESS LLC	YI	939.15	SAN MIGUEL MOUNTAIN	SAN DIEGO	CA	32	41	47.2	116	56	9.1	12.90999985
WQUW935	VEGAS WIRELESS LLC	YI	939.175	SAN MIGUEL MOUNTAIN	SAN DIEGO	CA	32	41	47.2	116	56	9.1	12.90999985
WQUW935	VEGAS WIRELESS LLC	YI	939.9	SAN MIGUEL MOUNTAIN	SAN DIEGO	CA	32	41	47.2	116	56	9.1	12.90999985

San Diego, CA 900 MHz Licensees within 15 miles of City Center

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Callsign	Licensee	Radio Service	Freq	LO Address	LO City	LO ST	LatDeg	LatMin	LatSec	LonDeg	LonMin	LonSec	Miles to Core San Deigo (mi)
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.1375	MOUNT SAN MIGUEL	ESCONDIDO	CA	32	41	49	116	56	7	12.93999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.15	MOUNT SAN MIGUEL	ESCONDIDO	CA	32	41	49	116	56	7	12.93999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.1625	MOUNT SAN MIGUEL	ESCONDIDO	CA	32	41	49	116	56	7	12.93999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.175	MOUNT SAN MIGUEL	ESCONDIDO	CA	32	41	49	116	56	7	12.93999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.1875	MOUNT SAN MIGUEL	ESCONDIDO	CA	32	41	49	116	56	7	12.93999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.2	MOUNT SAN MIGUEL	ESCONDIDO	CA	32	41	49	116	56	7	12.93999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.225	MOUNT SAN MIGUEL	ESCONDIDO	CA	32	41	49	116	56	7	12.93999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	936.675	MOUNT SAN MIGUEL	ESCONDIDO	CA	32	41	49	116	56	7	12.93999958
WPUG643	SAN DIEGO GAS & ELECTRIC COMPANY	YI	937.3875	MOUNT SAN MIGUEL	ESCONDIDO	CA	32	41	49	116	56	7	12.93999958
WQBH646	PDV Spectrum Holding Company	YI	936.9625	ATOP SANMIGUEL MTN	SAN DIEGO	CA	32	41	47.2	116	56	6.1	12.96000004
WQBH646	PDV Spectrum Holding Company	YI	937.9625	ATOP SANMIGUEL MTN	SAN DIEGO	CA	32	41	47.2	116	56	6.1	12.96000004
WQBH646	PDV Spectrum Holding Company	YI	938.4375	ATOP SANMIGUEL MTN	SAN DIEGO	CA	32	41	47.2	116	56	6.1	12.96000004
WQBH646	PDV Spectrum Holding Company	YI	939.45	ATOP SANMIGUEL MTN	SAN DIEGO	CA	32	41	47.2	116	56	6.1	12.96000004
WQBH646	PDV Spectrum Holding Company	YI	939.8875	ATOP SANMIGUEL MTN	SAN DIEGO	CA	32	41	47.2	116	56	6.1	12.96000004
WPKE327	PDV Spectrum Holding Company, LLC	GR	935.2125	SAN MIGUEL	SOUTH SAN DIEGO	CA	32	41	47.2	116	56	6.1	12.96000004
WPRL472	PDV Spectrum Holding Company, LLC	GR	936.2125	ATOP SAN MIGUEL	SAN DIEGO	CA	32	41	47.2	116	56	6.1	12.96000004
WPKE327	PDV Spectrum Holding Company, LLC	GR	935.225	ATOP RATTLESNAKE PEAK	SANTEE	CA	32	49	45.2	116	56	33.1	14.72000027
WPKE327	PDV Spectrum Holding Company, LLC	GR	935.25	ATOP RATTLESNAKE PEAK	SANTEE	CA	32	49	45.2	116	56	33.1	14.72000027